

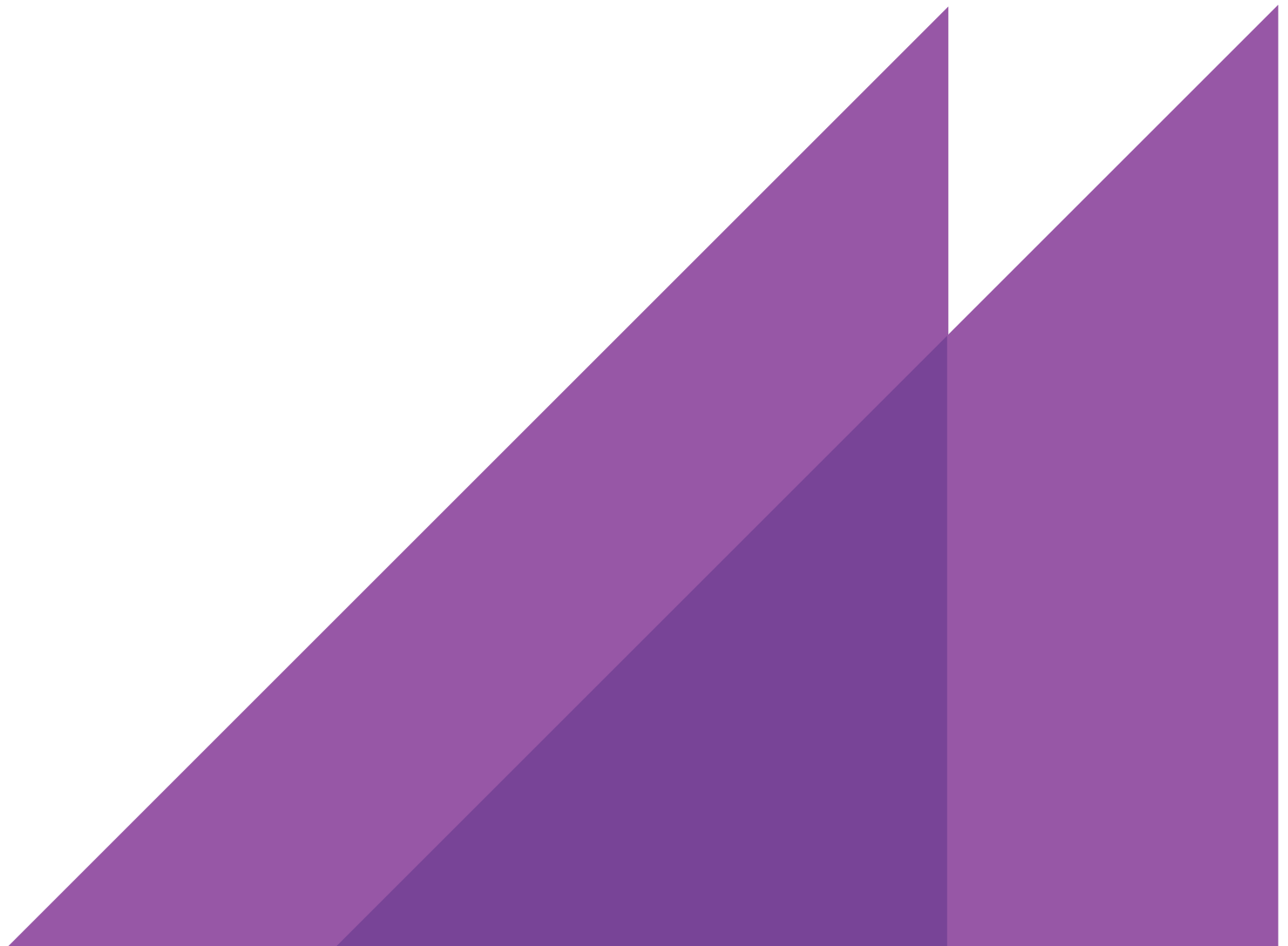
REPORT TO  
**THE MINERALS RESEARCH INSTITUTE OF WESTERN AUSTRALIA**  
JANUARY 2019

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# THE ECONOMIC IMPACT OF THE MINERALS RESEARCH INSTITUTE OF WESTERN AUSTRALIA

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FINAL REPORT





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# EXECUTIVE SUMMARY

## Scope of works and methodology

ACIL Allen Consulting ('ACIL Allen') was engaged by the Minerals Research Institute of Western Australia ('MRIWA') to conduct an economic impact assessment centred on the impact of the application of minerals sector research projects funded by the MRIWA. The assessment applies a case study approach to quantification, and seeks to value the impact of the application of technologies that the MRIWA's funding was used to conceptualise, develop, commercialise and/or implement in the Western Australian mining industry.

In undertaking the economic impact assessment itself, ACIL Allen has completed two separate but related pieces of analysis to provide a perspective on the economic impact of the MRIWA using the individual research program case studies analysed as part of the report. These are:

- a quantitative economic impact assessment using ACIL Allen's in-house Computable General Equilibrium (CGE) model *Tasman Global* to determine the direct and indirect economic impacts of the combined quantified benefits of the research programs studied. Further information on *Tasman Global* can be found in Appendix B. The outputs of the economic impact assessment have been produced for the Western Australian economy only.
- a benefit cost assessment (BCA), bringing in the quantitative impacts of the individual research programs and additional qualitative benefits uncovered through the assessment but which were not quantified for reasons discussed in the report. The BCA is useful as a means of establishing the extent to which the MRIWA is delivering value for money on the funds it is investing in research. The output of a BCA is a Benefit Cost Ratio (BCR), which is the identified benefits divided by the identified costs. It is also important to consider non-quantified or qualitative benefits when discussing the findings of a BCA.

In consultation with MRIWA, it was decided the economic impact assessment would centre on the quantification of forecast future realised benefits of research funded over the period 2018-19 to 2027-28. This "future focussed" economic impact assessment inherently involved the use of financial projections and modelling based on assumptions, which were derived via consultation with researchers and members of industry plus a review of research reports prepared by MRIWA funded researchers at the conclusion of research engagements.

## Research case studies

ACIL Allen sought MRIWA's assistance to build a group of research programs that were considered the most prospective by way of benefits to the State. Following this case study selection process, ACIL Allen and MRIWA agreed to centre the study on the assessment of the following six research program case studies.

1. **Grade Engineering:** a group of four projects (with additional projects to come) funded by MRIWA and completed as part of the CRC ORE II program. Grade Engineering seeks to improve mine economics in a range of ways through the application of advanced and real-time mineral grade assessment techniques.
2. **Wearable Technologies for Safety:** a single project which saw the MRIWA co-fund with Roy Hill Holdings the commercial trial of a technology product that aims to reduce the incidence of avoidable musculoskeletal injuries – currently in mining but with application across industry.
3. **mXrap Platform:** a nine project, multi-decade research program centred on building a more informed understanding of the science of rockburst and rockfall events in underground hard rock mines. The research has ultimately culminated in the development of a software platform that is in operation across a number of mine sites around the world, which acts as both a real-time data capture and information platform.
4. **Gold Exploration Targeting:** a four project research program centred on building a better understanding of the Yilgarn Craton in the Eastern Goldfields region of Western Australia. The program has resulted in development of a new, data-based exploration screening approach which has worldwide application, but in the short term may lead to additional gold and precious metals discoveries in the target region.
5. **Standardisation of Leaching Risk Assessments for Environmental Impact Assessments:** a two project program with the ChemCentre (another WA Government statutory authority) centred on the development of a more time and cost effective approach to environmental leaching risk assessments for new mine proposals. The project will result in a standardised approach to apply initially across the State's iron ore mine environmental assessment approval processes, reducing the time taken to go through the EIA process.
6. **Coiled Tubing Drilling Fluid:** a single research project centred on solving a specific problem as part of the commercialisation process of the DET CRC's coiled tubing drill rig exploration technology.

The six research program case studies selected for this economic impact assessment are presented below (Table ES 1).

**TABLE ES 1** MRIWA ECONOMIC IMPACT ASSESSMENT RESEARCH PROGRAMS

Research program and primary researcher	MRIWA projects	Total nominal MRIWA funding	Primary mineral	Research Priority Plan Area (P = Primary, S = Secondary)				
				Find More Resources	Expand the Mining Envelope	Increase Recoverable Value	Improve Productivity	Develop New Products & Markets
<b>Application of Grade Engineering to WA Mineral Producers</b> CRC ORE II	M485 M500 M503 M534	\$286,000*	Gold	S	S	P	S	
<b>Wearable Technologies for Safety</b> Soter Analytics	M498	\$25,000	Iron ore				P	S
<b>Rockburst Mitigation Technology</b> Australian Centre for Geomechanics	M328 M341 M355 M360 M366 M386 M406 M419	\$735,403^	Nickel				S	P
<b>Gold Exploration Targeting Technologies</b> CSIRO	M358 M377 M410 M452	\$1,063,000	Mineral exploration	P	S			

Research program and primary researcher	MRIWA projects	Total nominal MRIWA funding	Primary mineral	Research Priority Plan Area (P = Primary, S = Secondary)				
				Find More Resources	Expand the Mining Envelope	Increase Recoverable Value	Improve Productivity	Develop New Products & Markets
<b>Standardisation of Leaching Risk Assessments for Environmental Impact Assessments</b> ChemCentre	M432 M513	\$301,360	Iron ore				P	
<b>Coiled Tubing Drilling System Development</b> Deep Exploration Technologies CRC	M515	\$150,000	Mineral exploration	P			S	S

SOURCE: ACIL ALLEN CONSULTING

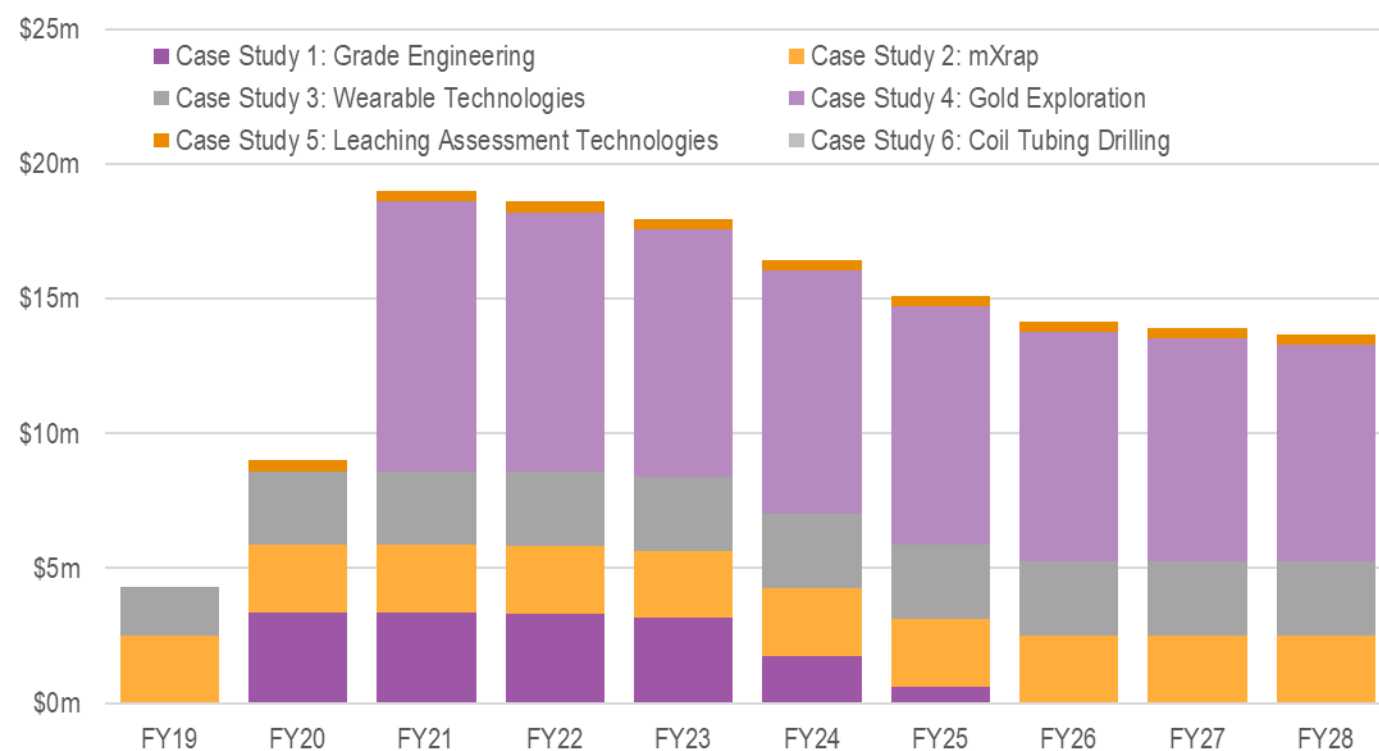
\*FUNDING FOR CRC ORE II TOTALS \$600,000 OVER SIX YEARS. THE VALUE LISTED AGAINST IT REFLECTS THE VALUE DISBURSED TO DATE

^MERIWA PROVIDED PROJECT COORDINATION SUPPORT FOR M386, WITHOUT A CONTRIBUTION TO PROJECT FUNDING

## Direct benefits of research case studies

Overall, the quantified benefits of the six research program case studies selected for analysis total \$142.2 million over the ten years 2018-19 to 2027-28 in real (2017-18) dollars, or approximately \$14.2 million per annum. The estimated annual benefits sorted by research program case study are presented below (Figure ES 1).

**FIGURE ES 1** SUMMARY OF DIRECT BENEFITS OF RESEARCH CASE STUDIES



SOURCE: ACIL ALLEN CONSULTING

The largest modelled benefit accrues as a result of Case Study 4 (CSIRO's Gold Exploration Technology research program), while Case Study 6 (DET CRC's Coil Tubing Drilling research program) does not produce any quantified benefits in this framework. This schedule of real benefits is the input into ACIL Allen's CGE model framework and are used to estimate the overall direct and indirect economic benefits of the combined research program case studies to Western Australia.

The table below (**Table ES 2**) summarises the total quantified benefits of each of the research program case studies included in this study, with real and discounted values included. Alongside each of the quantified benefits for each research program case study are a recap of the non-quantified benefits discussed in the body of the report.

**TABLE ES 2** MRIWA RESEARCH PROGRAM CASE STUDY BENEFITS, SUMMARY

Research Program Case Study	Gross benefit (\$m, 2018-19 dollars)	Discounted benefit (\$m, 2018-19 dollars, 15% discount rate)	Non-quantified benefits of research
Case Study 1: Grade Engineering	15.5	10.6	<ul style="list-style-type: none"> <li>– Application of technology to additional gold mines</li> <li>– Application of technology to additional mineral sectors</li> <li>– Additional positive impact on grades (ie larger impact magnitude)</li> <li>– Bring additional mines into scope</li> </ul>
Case Study 2: mXrap	25.1	14.5	<ul style="list-style-type: none"> <li>– Avoided human cost of seismic events</li> <li>– Additional research projects funded from mXrap profits</li> </ul>
Case Study 3: Wearable Technologies	26.6	14.9	<ul style="list-style-type: none"> <li>– Application to additional mines</li> <li>– Application to additional industries (non-minerals)</li> </ul>
Case Study 4: Gold Exploration	71.5	35.6	<ul style="list-style-type: none"> <li>– Potential for new mineral discoveries and additional mines</li> <li>– Development of new commercial business applying technology</li> </ul>
Case Study 5: Leaching Assessment Technologies	3.5	1.9	<ul style="list-style-type: none"> <li>– Cost savings for miners applying technology</li> <li>– Faster approvals, leading to improved mine economics</li> <li>– Application of technology to additional mineral sectors</li> </ul>
Case Study 6: Coil Tubing Drilling	N/A	N/A	<ul style="list-style-type: none"> <li>– Potential for new mineral discoveries and additional mines</li> </ul>
Total benefits	142.2	77.5	N/A

SOURCE: ACIL ALLEN CONSULTING



## Economic impact assessment

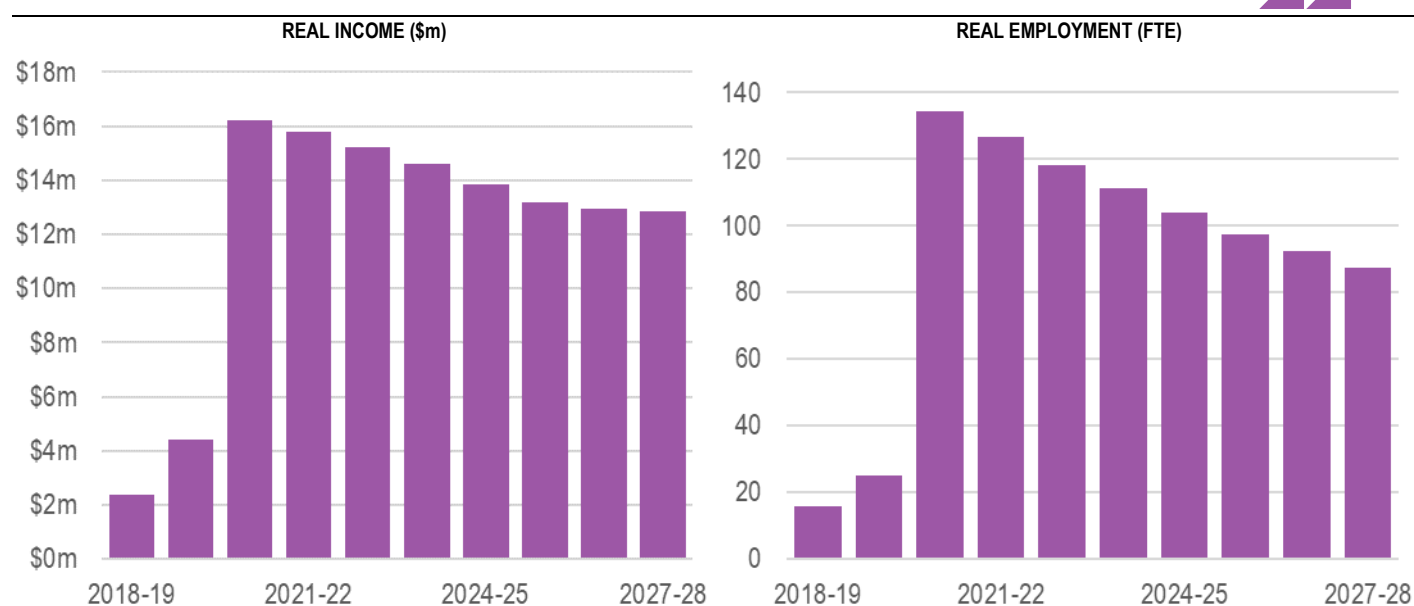
ACIL Allen has completed an economic impact assessment using its computable general equilibrium model *Tasman Global* to understand how the forecast direct benefits of the selected elements of the MRIWA's research program may impact on the Western Australian economy. The modelled scenario is the direct benefit calculation presented above, and discussed in more detail in Section 10.

ACIL Allen's economic impact assessment estimates that the funding allocated to MRIWA and its corresponding impact on the mining industry will provide a significant boost to the WA economy over the forecast period from 2018-19 to 2027-28. Based on ACIL Allen's CGE model, *Tasman Global*, it is estimated that the MRIWA funded research into the selected case studies will generate:

- **real incomes** of \$121.5 million over the forecast period, averaging \$12.1 million per annum;
- **real output** of \$166 million over the forecast period, averaging \$16.6 million per annum;
- **real consumption** impact of \$42.8 million over the forecast period, averaging \$4.3 million per annum;
- **government taxation** of \$6.6 million over the forecast period, averaging \$0.7 million per annum; and
- **employment** generation of 91.3 FTE jobs per annum over the forecast period.

The income and employment benefits are summarised below (Figure ES 2).

**FIGURE ES 2** ECONOMIC IMPACT ASSESSMENT OF MRIWA RESEARCH PROGRAM CASE STUDIES, REAL INCOME (\$M, 2017-18) AND EMPLOYMENT (FTE JOB YEARS)



SOURCE: ACIL ALLEN CONSULTING

## Benefit cost assessment

In order to estimate the net social benefit of the MRIWA's research program, ACIL Allen will use a Benefit Cost Assessment (BCA) framework. A BCA is a commonly used quantitative framework for logically analysing the social and economic costs and benefits of a particular policy, project or investment. The basis of a BCA is simple: for a given investment proposal or policy reform, a BCA compares the total forecast costs (including opportunity cost) to the community and economy of the investment or policy with the total forecast benefits. This determines whether the benefits outweigh the costs, and by how much.

The output of a BCA is typically expressed as a Benefit Cost Ratio (BCR) where total benefits are divided by total costs. A BCR of greater than one indicates that the net benefits of the policy, project or investment exceed the costs – this suggests economic value in investing in the option. The reverse applies for BCRs below one.

## BCA: Benefits calculation

For the purposes of this BCA, ACIL Allen has considered the benefits of the MRIWA accrue as the direct economic benefits calculated for the six research program case studies assessed as part of the economic impact assessment. However, in the BCA framework it is important to consider the extent to which the benefits generated are realised in Western Australia (a process which occurs in the CGE model for the purposes of the economic impact assessment).

ACIL Allen has attributed 100 per cent the relevant benefits to the MRIWA, as during stakeholder consultation each stakeholder identified that either the research program analysed for the case study wouldn't have happened, the research program would not be focussing on Western Australia, or both. ACIL Allen has included BCA ratios for a number of attribution percentages (50 per cent and ten per cent) in addition to the central assumption of 100 per cent attribution.

Overall, applying the local share ratios presented above to the discounted benefits calculated in Section 10 yields a **local direct benefit of \$54.5 million** in 2017-18 dollars. This benefit is used as the numerator in both of the quantitative BCA calculations.

## BCA: Costs calculation

ACIL Allen has included two different assessments of the "costs" associated with the MRIWA's funding of each of these six research programs.

### Direct State investment in research programs

The six research program case studies are made up of 20 individual MRIWA/MERIWA projects, 19 of which received funding from MRIWA/MERIWA and one in which MRIWA undertook a project coordination role. These projects are spread from 1998-99 to 2017-18, meaning their investment values need to be adjusted to reflect the value of the investment in today's dollars. In addition, it is important to consider a concept known as opportunity cost when reflecting the true cost of funds – particularly in a government context.

ACIL Allen has costed the **20 research projects that form the six research program case studies at \$4.4 million in 2017-18 dollars**. This represents a premium of around \$1.9 million on the nominal investments made by MRIWA/MERIWA in the respective year each project was funded.

### Cost of MRIWA to the State

The other approach to measuring costs for the purposes of this BCA is to determine the total State Government funding provided to MRIWA since its inception (1 February 2014) which has been spent by MRIWA with the intent of achieving its objectives under the Act. To complete this analysis, ACIL Allen received detailed profit and loss statements from MRIWA for the period 1 February 2014 to 30 June 2018, and converted these to a cash flow statement.

To date, ACIL Allen calculates MRIWA has cost the State Government \$13.7 million in real 2017-18 dollars.

However, the State Government has provided MRIWA with additional funds which are yet to be spent, but which sit in escrow awaiting disbursement for projects which have been approved but where milestones (such as research deliverables) have not yet been met. It is important to consider these as part of the "spent" funds for the purpose of the BCA. An opportunity cost should also be applied.

Adding these funds to the cost of MRIWA, and applying an opportunity cost, shows the **total cost of MRIWA to the State since its inception is calculated as \$17.4 million** in real 2017-18 dollars.

## BCA: Net benefits and Benefit Cost Ratios

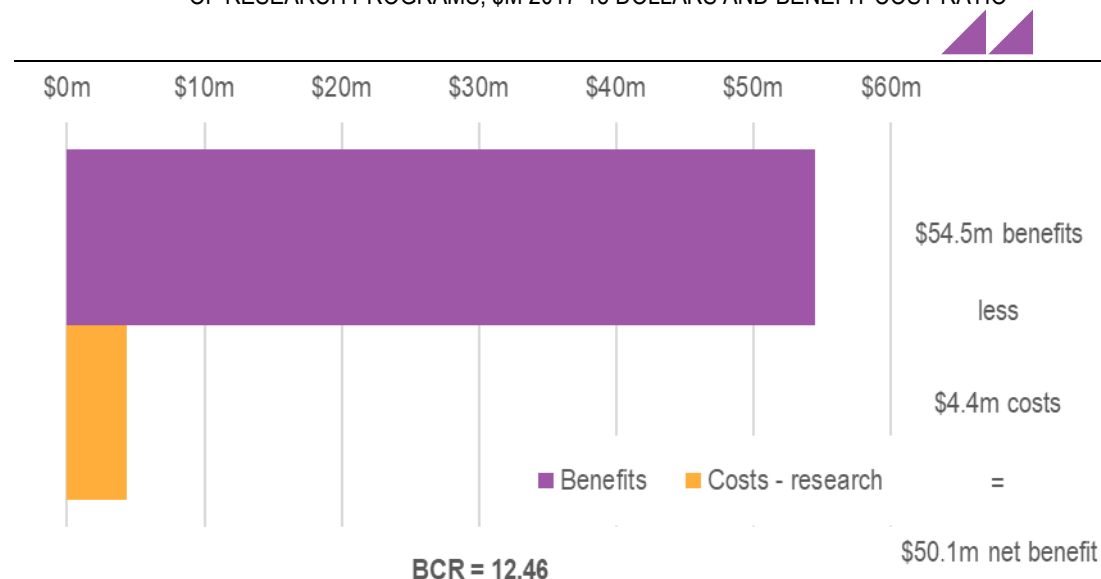
Using the information presented above, ACIL Allen can calculate a number of quantitative net benefits (benefits less costs) and benefit cost ratios (BCRs) for the MRIWA. These are presented below.

### MRIWA Research Program Benefits vs Research Program Costs

ACIL Allen estimates MRIWA's six research programs are forecast to deliver at least a net benefit of \$50.1 million, being that the research program is forecast to deliver benefits of \$54.5 million versus a research funding cost to the State of \$4.4 million. This BCA is summarised in the figure below (Figure ES 3).

Under the assumptions adopted above, the BCR of the MRIWA's research program as described above is 12.46, implying that for these research programs every dollar of State Government funding is forecast to produce \$12.46 of benefits. This is a significant result, even under conservative assumptions such as a compounding of the opportunity cost rate as a means of inflating costs and adopting an aggressive discount rate of 15 per cent.

**FIGURE ES 3** MRIWA BENEFIT COST ASSESSMENT, RESEARCH PROGRAM BENEFITS VS FUNDING OF RESEARCH PROGRAMS, \$M 2017-18 DOLLARS AND BENEFIT COST RATIO



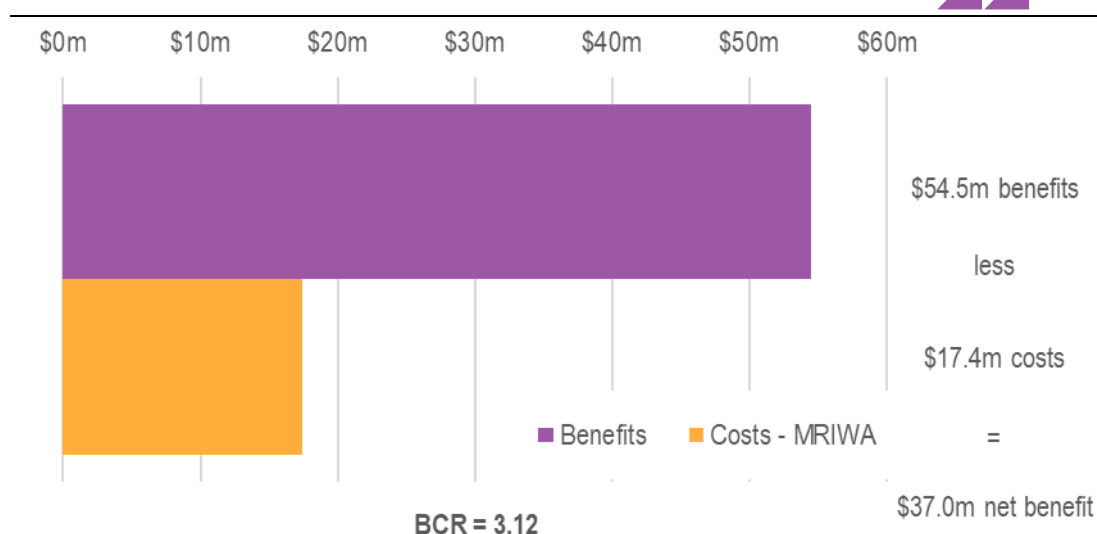
SOURCE: ACIL ALLEN CONSULTING (VALUES ROUNDED TO THE NEAREST \$100,000)

### MRIWA Research Program Benefits vs MRIWA Cost of Services

ACIL Allen estimates MRIWA's cost of services are forecast to deliver at least a net benefit of \$37.0 million, being that the research program is forecast to deliver benefits of \$54.5 million versus the cost to the State of the MRIWA's operations since its inception on 1 February 2014 of \$17.4 million. This BCA is summarised in the figure below (Figure ES 4).

Under the assumptions adopted above, the BCR of the MRIWA operations since its inception is 3.12, implying that for these research programs every dollar of State Government funding is forecast to produce at least \$3.12 of benefits. ACIL Allen has calculated this BCR as a means of demonstrating the role the MRIWA has played in fostering research projects that began under its precursor body. These are ultimately expected to result in the translation of significant benefits to the State's minerals industry well in excess of the MRIWA's cost of services in its current form.

**FIGURE ES 4** MRIWA BENEFIT COST ASSESSMENT, RESEARCH PROGRAM BENEFITS VS MRIWA COST OF SERVICES, \$M 2017-18 DOLLARS AND BENEFIT COST RATIO



SOURCE: ACIL ALLEN CONSULTING (VALUES ROUNDED TO THE NEAREST \$100,000)

### BCA: Unquantified benefits

In addition to the quantified benefits, there are a number of other benefits delivered by the MRIWA which are more intangible in nature. These are benefits which ACIL Allen has uncovered during its program of stakeholder consultation, which it considers important to understanding the overall benefit of MRIWA to the State of Western Australia. These qualitative benefits include:

- The MRIWA's role in creating linkages between researchers and industry members, which would have otherwise not formed. These linkages can result in knowledge transfer or the development of research programs which are entirely separate from MRIWA but still deliver upon its priorities. These kinds of relationships have not been quantified as part of this benefit cost assessment.
- One of the MRIWA's Research Priority Plan areas is Find More Resources. ACIL Allen made a conceptual decision to exclude these from its scope of quantification, as the development of a new mine requires more than simply finding the resource. Notwithstanding, if technologies supported by MRIWA resulted in the development of just one mine in Western Australia the State Government's investment in MRIWA will have a positive benefit cost ratio.
- The MRIWA helps enhance Western Australia's reputation as a positive place for the minerals industry, by signalling the State's interest in and desire to foster the minerals industries. This may attract global multi-national corporations or smaller companies to set up a base of operations in the town.

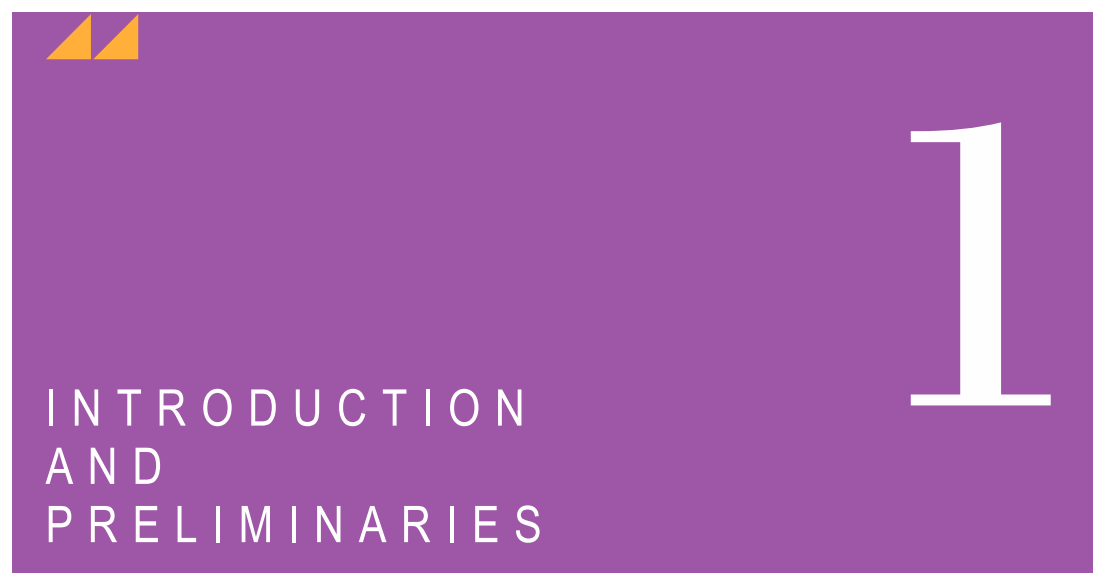
### Overall findings

Overall, it is clear from ACIL Allen's analysis that the MRIWA delivered significant value to the State of Western Australia. Each of the individual direct benefits of the six research program case studies, the overall economic impact assessment, or the benefit cost assessment concur that the MRIWA affords the Western Australian Government a number of benefits in excess of the MRIWA to Western Australians.

ACIL Allen's conservative approach to case study quantification has still yielded a significantly positive result, with direct benefits to Western Australia exceeding the MRIWA's annual budget for the past 4.5 years at over 3.5 to one. When compared just to the MRIWA's funding of individual research programs, the benefits are enormous: 12.90 to one, without any consideration of the "Find More Resources" aspect of the MRIWA's research priority plan.

With regards to the economic impact assessment, ACIL Allen finds the MRIWA's research program delivers \$121.5 million in real income benefits to Western Australian businesses, people and government agencies. The MRIWA's research program also results in the creation of 913 job years over the ten year study period, and conservatively delivers an additional \$6.6 million in State Government taxes.

Considering the above, ACIL Allen's conclusion is the MRIWA delivers significant value for money for the Western Australian Government, and produces real and tangible benefits to the Western Australian minerals sector that would otherwise not be realised.



## 1.1 Introduction

The MRIWA is an independent statutory authority of the Western Australian Government, and is established under the Minerals Research Institute of Western Australia Act 2013 ('the Act'). The Act states the MRIWA exists **for the purpose of fostering and promoting minerals research for the benefit of the State [Western Australia]**. To do this, the MRIWA undertakes a number of functions on behalf of the State, being to (amongst the usual business of a government agency):

- undertake, procure or manage minerals research projects,
- provide financial assistance for minerals research and other activities,
- keep records about minerals research,
- confer and collaborate on minerals research,
- maintain current knowledge of minerals research being undertaken in the State and elsewhere, and
- promote public awareness of and public interest in minerals research.

To do this, MRIWA exists primarily as a funding agency which procures research centred on the development of new information, technologies, processes and approaches for the benefit of the Western Australian minerals sector. MRIWA also acts as a clearinghouse for researchers and industry members, providing a conduit to build research projects which may have otherwise not formed whether they end up receiving MRIWA funding or not. The organisation is also an important player in fostering collaboration and transferring knowledge, via a range of formal and informal gatherings such as "Tech Talks", workshops and symposiums. In recent years, MRIWA has developed a PhD scholarship program, funding up to half a dozen new PhD students at Western Australian universities per annum since 2013-14.

MRIWA's activities are guided by its Research Priority Plan ('RPP'), which was last reviewed in June 2013. The RPP articulates the research priorities of MRIWA, and helps guide both prospective research proponents and the board of MRIWA when forming proposals and when making decisions about which projects to fund respectively. It was developed in close consultation with the WA minerals industry in a structured process that considered a total of 79 minerals sector needs and Australia's current research capabilities.

The result is five core "research themes", which have guided MRIWA's decision making since. These are:<sup>1</sup>

- **Find More Resources:** develop methods and tools to meet the challenging exploration environments in Western Australia

<sup>1</sup> MRIWA. 2013. *MRIWA Research Priority Plan, June 2013*. Accessed online at <http://www.mriwa.wa.gov.au/>

- **Expand the Mining Envelope:** allow deeper mining of more geotechnically challenging ore bodies
- **Increase Recoverable Value:** develop advanced modelling for processing circuits to efficiently recover minerals from increasingly low grade and complex mineralisation.
- **Improve Productivity:** reduce the operating and capital costs of mining in Western Australia.
- **Develop New Products and Markets:** develop processes that lead to new mineral products and markets for Western Australia.

All of these areas have a common objective at their heart: optimisation of the local benefits of research, including delivering increased State revenues.

To assist it in achieving its objectives, MRIWA has established a rigorous advisory structure centred on the MRIWA board as the final decision maker regarding project funding. The board is supported by a research advisory committee, which in turn is supported by five “theme” committees (one for each research theme in the RPP) that are responsible for screening and providing advice for the purpose of improving on proposals which are at first assisted by the MRIWA executive.

The MRIWA has existed as MRIWA since 1 February 2014. Prior to this the authority was constituted as the Minerals and Energy Research Institute of Western Australia (‘MERIWA’). MERIWA had existed since it was established by legislation in 1987, and was similarly tasked with the responsibilities above though was also able to fund projects centred on the State’s energy resources. While established as a new entity, MRIWA inherited all of MERIWA’s assets, rights and liabilities and other material aspects of MERIWA (such as the MERIWA CEO, all applications in progress, and all projects which had received funding but were not yet completed).

Ultimately, the MRIWA exists to deliver benefits to the Western Australian minerals sector, through research translation and the adoption of techniques, systems, processes and approaches. From time to time, the MRIWA checks in to ensure it is achieving this objective by commissioning an economic impact assessment of a selection of its projects.

### 1.1.1 ACIL Allen’s scope of works

ACIL Allen Consulting (‘ACIL Allen’) was engaged by the Minerals Research Institute of Western Australia (‘MRIWA’) to conduct an economic impact assessment centred on the impact of the application of minerals sector research projects funded by the MRIWA. The assessment applies a case study approach to quantification, and seeks to value the impact of the application of technologies that the MRIWA’s funding was used to conceptualise, develop, commercialise and/or implement in the Western Australian mining industry.

In 2015 MRIWA engaged Deloitte Access Economics to complete a similar economic impact assessment of selected projects funded by both MERIWA and MRIWA. The Deloitte Access Economics study centred on the benefits of five individual research projects over a ten year period from 2008-09 to 2019-20. The study found a real output benefit of \$90.4 million to the State (NPV 7%, 2014-15 dollars) under its central scenario over the study period, which exceeded the present value of all research projects funded by MERIWA/MRIWA from 1990 to 2015.<sup>2</sup>

ACIL Allen’s study builds on the sound approach taken by Deloitte Access Economics by seeking to quantify a series of research projects that are part of a chain of MERIWA/MRIWA-funded projects (a ‘research program’) that have resulted in the development of a new technology or approach which has produced or is considered very likely to produce an identifiable benefit to minerals producers in Western Australia.

ACIL Allen’s general approach was to quantify the application of these new technologies or approaches using real examples of the operations of companies or industries, taking a conservative approach (such as applying a new approach to one or two companies, or applying a sector-wide technology to a sub-set of a single industry) as a means of establishing a baseline level of quantitative impact. The intent of this approach is to account for the uncertainty associated with the application of new technologies or approaches, while also ensuring the analysis is grounded in the potential real

<sup>2</sup> Deloitte Access Economics. 2015. *Minerals Research Institute of Western Australia: Economic Impact Assessment, August 2015*. Received from MRIWA.



world application of these technologies or approaches. Benefits have been quantified for the ten year period 2018-19 to 2027-28, and are for the Western Australian minerals sector only.

The primary means of gathering evidence and information to inform the calculation of research program benefits was stakeholder consultation. ACIL Allen held detailed stakeholder consultation sessions with researchers involved in the research programs analysed for the purposes of the assessment, and conducted targeted follow up consultations to fill in information gaps. Where required, ACIL Allen also consulted with industry representatives that were deriving benefits from the research program, or were likely to do so in the future. Other information sources included company annual reports, MRIWA research reports and other materials, the Australian Bureau of Statistics and various State Government data sources (such as the Department of Mines, Industry Regulation and Safety minerals and work safety databases).

In undertaking the economic impact assessment itself, ACIL Allen has completed two separate but related pieces of analysis to provide a perspective on the economic impact of the MRIWA using the individual research program case studies analysed as part of the report. These are:

- a quantitative economic impact assessment using ACIL Allen's in-house Computable General Equilibrium (CGE) model *Tasman Global* to determine the direct and indirect economic impacts of the combined quantified benefits of the research programs studied. Further information on *Tasman Global* can be found in Appendix B. The outputs of the economic impact assessment have been produced for the Western Australian economy only.
- a benefit cost assessment (BCA), bringing in the quantitative impacts of the individual research programs and additional qualitative benefits uncovered through the assessment but which were not quantified for reasons discussed in the report. The BCA is useful as a means of establishing the extent to which the MRIWA is delivering value for money on the funds it is investing in research. The output of a BCA is a Benefit Cost Ratio (BCR), which is the identified benefits divided by the identified costs. It is also important to consider non-quantified or qualitative benefits when discussing the findings of a BCA.

The remainder of this chapter provides an overview of this report and introduces key terms.

## 1.2 Structure of this report

This report is broken into three parts and a number of chapters within these parts. The structure has been developed so that individual research program case studies can be pulled out of the report as standalone documents. Each part and relevant chapters are outlined below.

**Chapter 2: The WA Mining Sector** provides some contextual information regarding the Western Australian minerals industry, and its various cycles of growth and consolidation over the past century. This chapter is designed to inform the reader of the importance of the minerals sector to the State of Western Australia, and provide a view on its cyclical history.

**MRIWA Research Case Studies (Chapters 3 to 10)** introduce and discuss the six individual research program case studies. These chapters include a discussion of the research program and its potential benefits, the method of calculating a benefit of the application of the research, and a discussion of any additional benefits which are not quantified. At the end of the chapter, a consolidated view of the quantified benefits of the research program case studies is presented, which is used as both the input for the economic impact assessment and the numerator for the benefit cost assessment.

**The Economic Impact of the MRIWA (Chapters 11 to 13)** provide for the results of the economic impact assessment, benefit cost assessment and overall summary of the report.

## 1.3 Key terms, abbreviations and assumptions

Where possible, ACIL Allen has avoided the use of technical jargon in the presentation of this report. However there are a range of economic terms and acronyms used to discuss modelling inputs and outputs. These are presented below.



### 1.3.1 Terms used

The following terms and abbreviations have been used in this report.

**TABLE 1.1** TERMS USED

Term	Description
<b>Employment</b>	The number of full time equivalent job years created as a result of a project or expenditure in the economy, which includes direct and indirect (flow-on) employment.
<b>Gross Operating Surplus</b>	<p><i>A measure of the gross income less expenditure on intermediate inputs and wages</i></p> <p>Gross Operating Surplus (GOS) is an economic measure of the income earned by the capital employed by a project or economy. It is typically calculated as a residual factor of total income earned by a project less expenditure on intermediate inputs and wages paid. It is different to accounting profit as it includes a number of the deductions and other outflows a company would typically remove from the measure of its profitability; it also includes all taxes payable to governments.</p>
<b>Gross product or real economic output</b>	<p><i>A measure of the size of an economy</i></p> <p>Gross product is a measure of the output generated by an economy over a period of time (typically a year). It represents the total dollar value of all finalised goods and services produced over a specific time period and is considered as a measure of the size of the economy. At a national level, it is referred to as Gross Domestic Product (GDP); at the state level, Gross State Product (GSP); while at a regional level, Gross Regional Product (GRP).</p>
<b>Gross Value Added</b>	<p><i>A measure of the value of goods and services produced in an industry or sector of an economy.</i></p> <p>Gross Value Added (GVA) is the output of an industry or sector minus intermediate consumption. GVA therefore represents the value of all goods and services produced, minus the cost of all inputs and raw materials used to produce that good or service. Unlike Gross Product, GVA does not include the value of taxes minus subsidies.</p>
<b>Input-Output Tables</b>	Input-Output (I-O) tables capture the direct and indirect effects of expenditure by capturing, for each industry, the industries it purchases inputs from and also the industries it sells its outputs to. For example, the I-O model for Western Australia captures purchases from and sales to industries located in Western Australia, as well as imports from outside of Western Australia.
<b>Job years</b>	Real employment is measured in job years. A job year is employment of one full time equivalent (FTE) person for one year. Alternatively it can be expressed as one 0.5 FTE person for two years.
<b>Net present value (NPV)</b>	<p>The value of a future stream of income (or expenses) converted into current terms by an assumed annual discount rate. The underlying premise is that receiving, say, \$100 in 10 years is not 'worth' the same (i.e. is less desirable) than receiving \$100 today.</p> <p>For the purposes of this study, NPV calculations have been made based on a discount rate of 4 per cent, 7 per cent and ten per cent.</p>

Term	Description
<b>Real and nominal dollars</b>	<p>Nominal dollars are dollars that are expressed in the actual dollars that are spent or earned in each year, including inflation effects. Real dollars have been adjusted to exclude any inflationary effects and therefore allow better comparison of economic impacts in different years. Over time, price inflation erodes the purchasing power of a dollar thereby making the comparison of a dollar of income in 2063 with a dollar of income in 2018 invalid. Adjusting nominal dollars into real dollars overcomes this problem.</p> <p>All values are expressed in real dollar terms with a base year of 2018-19, unless otherwise stated.</p>
<b>Real consumption</b>	<p><i>A measure of household expenditure in an economy</i></p> <p>Real consumption is a measure of the value of goods and services purchased by the household sector in an economy. It is a part of aggregate demand, and generally speaking is the largest individual component of the economy. Real consumption is funded by real income and its various components, and can be supplied in an economic sense by increased domestic production or imports of goods and services.</p>
<b>Real income</b>	<p><i>A measure of the welfare of residents in an economy through their ability to purchase goods and services and to accumulate wealth</i></p> <p>Although changes in real economic output are useful measures for estimating how much the output of the economy may change due to a change in policy, changes in real income are also important as they provide an indication of the change in economic welfare of the residents of a region through their ability to purchase goods and services.</p> <p>Real income measures the income available for final consumption and saving after adjusting for inflation. An increase in real income means that there has been a rise in the capacity for consumption as well as a rise in the ability to accumulate wealth in the form of financial and other assets. The change in real income from a development is a measure of the change in the economic welfare of residents within an economy.</p>

SOURCE: ACIL ALLEN CONSULTING

### 1.3.2 Acronyms used

The following acronyms have been used in this report.

**TABLE 1.2** ACRONYMS USED

Acronym	Description
ABS	Australian Bureau of Statistics
ACG	The Australian Centre for Geomechanics
AUD, A\$ or \$	Australian dollars (default unless otherwise specified)
CAPEX	Capital expenditure
CGE	Computable General Equilibrium (model)
CPI	Consumer Price Index
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FTE	Full Time Equivalent
FY	Financial year
GSP	Gross State Product

Acronym	Description
GVA	Gross Value Added
NPV	Net Present Value
MERIWA	Minerals and Energy Research Institute of Western Australia
MRIWA	Minerals Research Institute of Western Australia
UWA	The University of Western Australia
WA	Western Australia
WPI	Wage Price Index
SOURCE: ACIL ALLEN CONSULTING	

### 1.3.3 Key assumptions

In addition to the above, ACIL Allen has made a number of technical modelling assumptions which are required to facilitate both the economic impact assessment and benefit cost assessment. These assumptions are detailed in the relevant chapters (Section 10 for the research program case studies, Section 11 for the economic impact assessment, and Section 12 for the benefit cost assessment). The assumptions, the value, and where the assumption is required, are presented in the table below.

**TABLE 1.3** KEY MODELLING ASSUMPTIONS

Assumption	Value	Where assumption is used
Discount rate – benefits	15%	Calculation of future benefits of research case studies
Opportunity cost	4%	Calculation of costs of MRIWA to State Government
Direct benefit retention – major mining companies	12%	Calculation of future benefits of research case studies Calculation of economic impacts of MRIWA funded research cases studies
Direct benefit retention – other mining companies	100%	Calculation of future benefits of research case studies Calculation of economic impacts of MRIWA funded research cases studies
Inflation rate – historic	Per ABS	Calculation of costs of MRIWA to State Government
Inflation rate – future	2.5%	Bringing future nominal costs to real 2017-18 dollars
Gold price (constant)	\$1,675/ounce	Calculation of benefits associated with Case Study 1
Iron ore price (constant)	AU\$91.20/tonne	Calculation of benefits associated with Case Study 2
SOURCE: ACIL ALLEN CONSULTING		



Western Australia's mining industry has been the most important sector to the State for most of its history. With immense natural resources and a geographic advantage in accessing key markets, the State's mining industry has been through a number of waves of development over the past 150 years. As a means of demonstrating the importance of the industry to Western Australia, ACIL Allen has included a brief history of key events in the industry in this chapter, before discussing the role of the minerals industry in Western Australia today.

## 2.1 A brief history of the Western Australian minerals industry

The mining industry in Australia dates to the end of the 18<sup>th</sup> century and has been an important primary industry for the nation.<sup>3</sup> The industry has contributed to construction, fuel, industrial raw materials as well as export income. The industry has also contributed to the dispersal and inflow of population on the back of rail and port infrastructure. The mining industry has been a catalyst for the growth and development in Western Australia. Since the origins of the industry in the 1890s, mining has led to inflows of population, wealth for companies, generated growth for local businesses, economic growth and returns to State.

Victoria and New South Wales were home to Australia's first gold rush in the 1850s which led to a transformation of colonies into progressive cities.<sup>4</sup> The discoveries led to an influx of immigrants which brought skills and knowledge to communities. This influx of population and increased mining activity contributed to the growth of the economy and infrastructure.

Leading up to the 1900s Australia became one of the world's largest producers of Gold (presented in figure 1.6). The growth in gold mining during this period led to population growth, economic growth and started to shape the national identity in mining. Later in the century, discoveries in WA led to the State's first gold rush which occurred nearly 40 years after the east-coast.

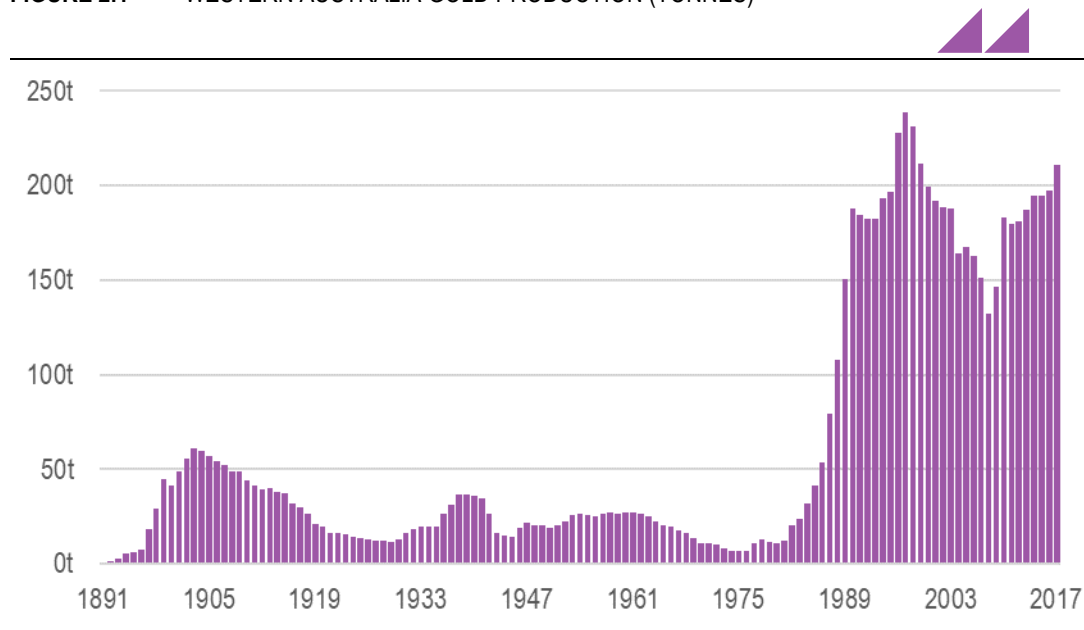
One of the most important developments in WA's mining history was the Gold Rush in the late 1890s upon discoveries in Kalgoorlie and Coolgardie.<sup>5</sup> In the 1890s, WA's population grew from approximately 50,000 to 180,000 people.

Since 1890, WA has accounted for over 60 per cent of gold production in Australia. Gold production boomed in the 1890s, resurged in the 1930s and boomed again in the 1980s. The production levels reached during the 1980s boom have extended to the present day with approximately 200T being produced each year (**Figure 2.1**).

<sup>3</sup> ABS (2001), Special Article - The Australian Mining Industry: From Settlement to 2000 (Oct, 2000)

<sup>4</sup> State Records Office of Western Australia, Mining Records.

<sup>5</sup> National Museum Australia, Gold Rushes (<http://www.nma.gov.au/defining-moments/resources/gold-rushes>).

**FIGURE 2.1** WESTERN AUSTRALIA GOLD PRODUCTION (TONNES)

SOURCE: ACIL ALLEN CONSULTING, DMIRS &amp; DIIS

Western Australia's nickel industry first began production in the late 1960s, in the eastern parts of the State. Western Mining Corporation's Kambalda nickel mine was the first major nickel producing mine, while a miniature price boom occurred in 1969 on account of the Vietnam War (nickel is used to produce stainless steel among other metal alloys). Today, the State's major nickel producer is BHP's NickelWest, which owns a number of mines and processing facilities through the Goldfields region of Western Australia.

Around this time, the State's first bauxite mine was developed in the Darling Ranges. Over time a downstream processing industry developed, with Alcoa of Australia building a vertically integrated supply chain that saw Western Australian bauxite refined into alumina in Kwinana, Pinjarra or Wagerup and sent on to aluminium smelters on the east coast of Australia. Alcoa's activities were one of the key factors behind the development of the Dampier to Bunbury Natural Gas Pipeline, an important catalyst for Western Australia's economic development.<sup>6</sup>

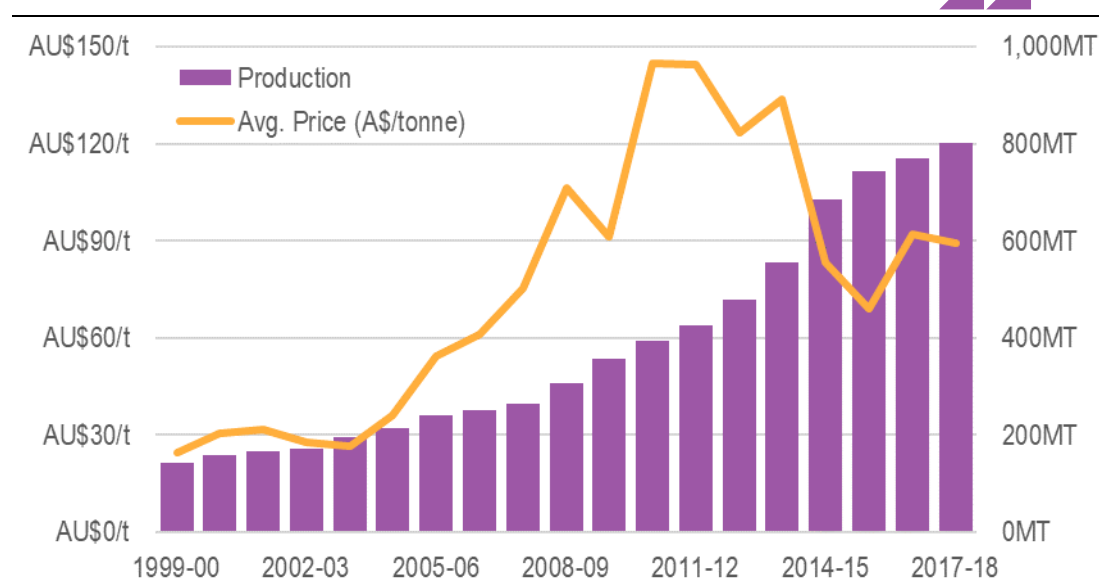
The most significant mineral of all though has been iron ore, which has experienced a number of cycles in the State's history. The first boom was in the 1960s following the removal of a trading embargo (previously iron ore was reserved for domestic steel production). This led to an increase in the production of iron ore, initially on account of demand from Japan and in more recent times China.

As one of Australia's major trading partners, China has played a major role in the growth of WA's mining industry. China's transition from a largely agriculture-based economy to a modern industrial sector between the 1960s and 1990s led to increased demand for commodities such as coal and iron ore for energy and steel production. In the second half of the decade, China's demand for iron ore grew significantly. Its economy entered a super cycle experiencing average economic growth 9.9 per cent in the 1990s and 10.4 per cent in the 2000s respectively on average.

This spurred the so-called mining boom in Western Australia. The boom began circa 2003 when the price of commodities rose, especially for iron ore (**Figure 2.2**). The surge in demand was driven by demand, predominantly from China's growth.

<sup>6</sup> DBP. 2018. *Australian Gas Infrastructure Group, the Dampier to Bunbury Gas Pipeline: Pipeline History*. Accessed online at <http://www.dbp.net.au/>

**FIGURE 2.2** WA IRON ORE, ANNUAL PRODUCTION (MT) VS AVERAGE AUD PRICE (62% FE CONTENT FOB CHINA IMPORT TERMINAL PRICE)



SOURCE: ACIL ALLEN CONSULTING, DMIRS

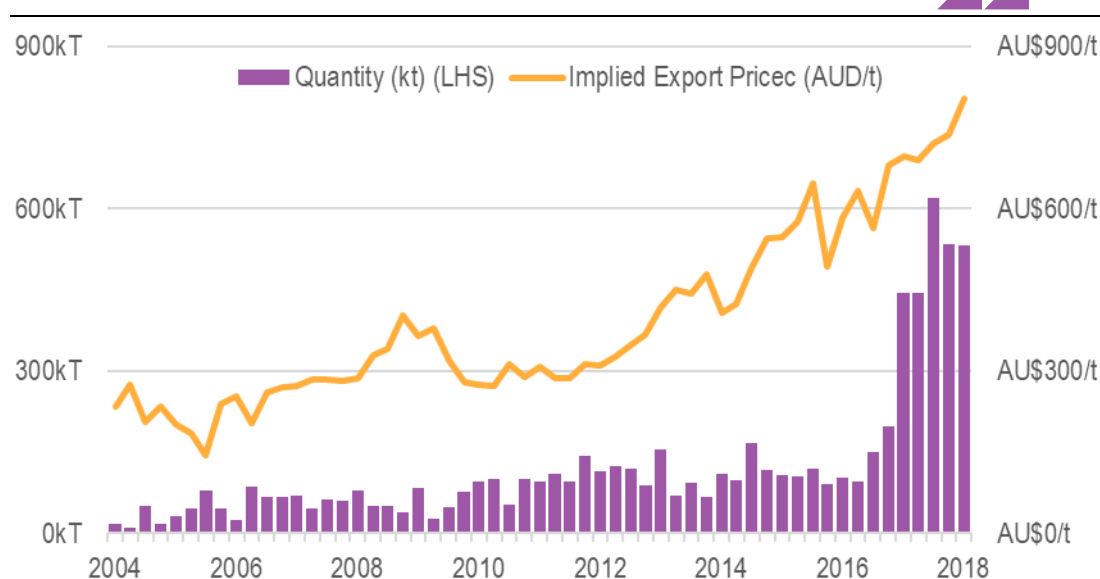
The increase in commodity demand from Asia has led to a substantial increase in mining investment for the State. Since 1990, WA's share of national mining investment has averaged 52 per cent and increased from \$1.9bn to \$20.5bn between 1990 and 2017.<sup>3</sup> Mining investment in WA peaked in 2012-13 at \$51.0bn. The increase in investment prefaced the boom as mining investment includes buildings, infrastructure, equipment, plant and machinery which all lead to increased future production. For the economy, the increase in mining investment has meant more job opportunities, increased export sales, higher royalty receipts for the state and widespread economic benefits. As an example, employment in the WA mining sector peaked in 2012 and royalty revenue peaked in 2013 which was at the height of the modern mining boom in the state.

Royalty receipts have significantly increased between 1983 and the 2017. In 1983, royalty receipts were \$118.1m, largely from iron ore. By 2000, receipts had surpassed one billion dollars largely driven by petroleum receipts. Between 2009 and 2017, iron ore returned to be the dominant source of return for the State. By 2017, mining royalties returned \$5.2bn to the State with 87 per cent coming from iron ore sources.

WA's contribution to global iron ore production has been the most profound of any major producing nation, with the State's production increasing from approximately 450 million tonnes in 2011 to over 800 million tonnes in 2016. As a comparison, WA's contribution to world production of iron ore was 33 per cent in 2017. This not only highlights the global demand for the commodity but also the competitiveness of the WA iron ore industry on a global stage.

More recently, mining in WA has experienced significant growth in lithium mining. Since 2013, WA has been the largest producer of lithium and has accounted for over 40 per cent of global production (**Figure 2.3**). The State has four producing mines and exported approximately 866,000 tonnes of products (\$601m in sales) containing the metal in 2016-17. The increased demand for the precious metal comes from the rechargeable lithium-ion batteries which are used for energy storage and electric vehicles. Demand is predicted to increase by approximately 15 per cent over the next few years.<sup>9</sup>

**FIGURE 2.3** WEST AUSTRALIAN LITHIUM (SPODUMENE CONCENTRATE) PRODUCTION AND IMPLIED EXPORT PRICE (AUD/T)



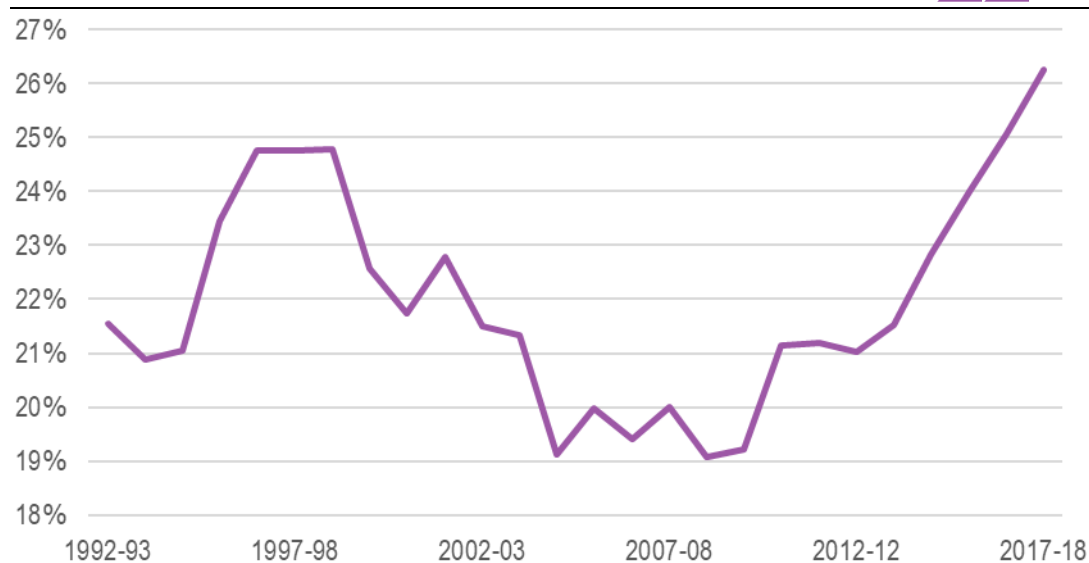
SOURCE: ACIL ALLEN CONSULTING, DMIRS

WA is well suited for lithium mining due to its proximity to key markets, short construction and ramp-up times and relatively low costs of capital.

## 2.2 Western Australia's minerals industry today

Today, the minerals industry is the most important industry in Western Australia. In the 2017 financial year, mining accounted for approximately 36 per cent of total gross value added (GVA) for the Western Australian economy, the largest single sector of any sector in any State or Territory. The mining industry has been the State's largest industry for some time, though its share of activity has increased in recent times on account of the mining boom (Figure 2.4).

**FIGURE 2.4** WA MINING INDUSTRY SHARE OF WA GROSS VALUE ADDED



SOURCE: ACIL ALLEN CONSULTING, ABS



In line with this, the mining industry has also provided significant employment opportunities for the population of WA. The industry employed 105,200 people at the end of the September quarter of 2018, down from a boomtime high of 113,700 but still well above the levels of ten (71,800) and 20 (30,200) years ago, in a sign of the magnitude of the industry's recent growth. According to the Department of Mines, Industry Regulation and Safety iron ore is the State's largest employing mineral, with 48 per cent of total mining sector employees linked most closely with iron ore. Gold (26 per cent) is the only other mineral commodity with more than a ten per cent share of employment, with a range of minerals accounting for around five per cent of the State's mineral industry employment.

The vast majority of Western Australia's mineral production is for export, with the mining industry generating \$92.4 billion of export earnings in the 2018 financial year, or 71 per cent of the State's total export earnings. Similarly, Western Australia's mineral industry accounted for 29 per cent of Australia's total merchandise exports in 2017-18, similarly the largest single industry-state share of any combination across the States.

Mining is also an important driver of State taxes, with the sector's \$5.2 billion in royalty income accounting for 18 per cent of WA General Government revenue in the 2017-18 financial year. The minerals industry is also an important source of payroll tax, transfer duty and regulatory (such as mining leases and exploration licences) fees and charges. Minerals industries are also the major customer of many of Western Australia's State-owned ports, delivering the State additional revenue as minerals leave the State's shores bound for overseas customers.

### 2.2.1 Changing times underscore the role of mining innovation

While these are all impressive figures, the future of Western Australia's minerals industry is far from secure. The industry is intensely competitive, with the quantity of minerals in the ground one of many factors which ultimately decide where mining activity occurs around the world. Western Australia bore the brunt of the mineral commodity cycle in the middle part of the last decade, when prices for most major commodities dropped from record highs. Suddenly minerals producers were operating in a fundamentally different environment, where cost control and productivity became much more important than building new supply.

Western Australia's iron ore industry is a case in point. The rush to supply rampant demand growth emanating out of China and other parts of developing Asia saw the State's major iron ore producers rush to build new mines and associated infrastructure; once the new capacity was built and producing prices began to fall and the producers who had geared for growth suddenly faced new headwinds. Those headwinds have seen the State's major producers shed significant costs in recent years, as demonstrated by the global cost curve for iron ore (**Figure 2.5**).

The chart below shows the extent to which the global iron ore mining industry has reduced its cost of production in recent years. The blue line represents the cost of producing a tonne of iron ore (adjusted to a 62 per cent iron grade) at each marginal tonne of production in 2013; the coloured columns represent the cost of producing that same marginal tonne in 2017. The darker bars represent Western Australian mines while the lighter shades show non-Australian mines. At each point along the curve, the marginal cost of production is significantly lower in 2017 versus 2013. It is likely cost reduction has continued to gather pace since this data was derived.

In response to these pressures, the State's iron ore industry is seeking ways to become more productive and to reduce cash costs; seeking higher grade iron ore deposits<sup>7</sup>, introducing automation and remote operations,<sup>8</sup> and relentlessly optimising their operations from mine head to port.<sup>9</sup> With the miners having cut significant cost out of their respective businesses, the way forward is continued investment in technology and innovation as a way to both improve their existing operations and help spur new mines or approaches to mining the State's rich resources.

The MRIWA is an important part of this emerging story. While MRIWA has been around for some time, its role is arguably more vital than ever as a catalyst for mining innovation and technology

<sup>7</sup> See: Thompson, B. 2018. *Rio Tinto counting on Koodaideri in \$2.2bn new iron ore mine spend*; Letts, S. 2018. *BHP approves \$4b iron ore mine as new boom hits the Pilbara*; Newell, D. 2018. *FMG green lights \$1.7b Eliwana with 500 jobs to come*.

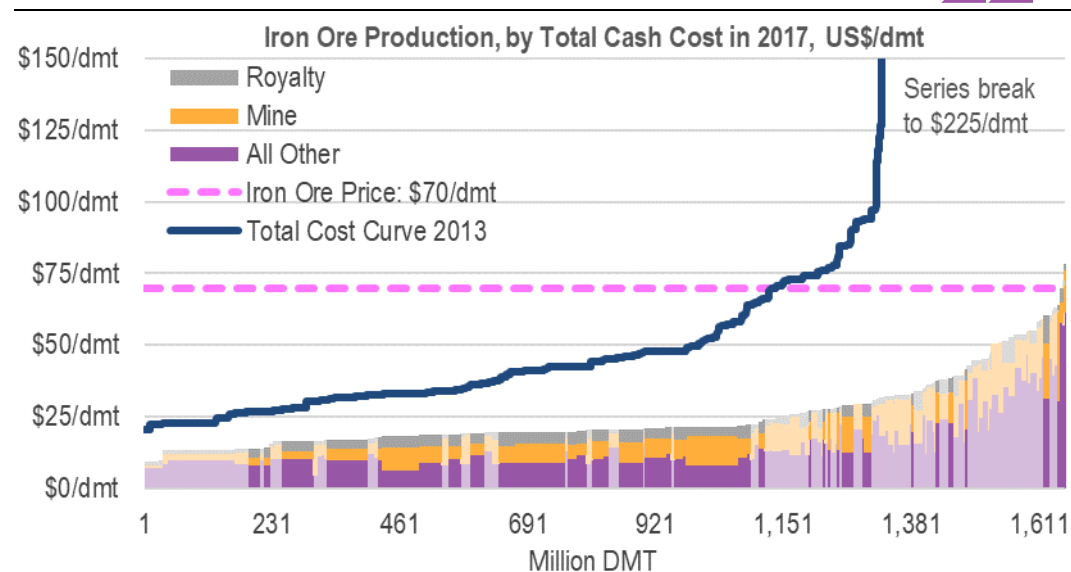
<sup>8</sup> Hastie, H. 2018. *One HAL of a ride: Rio's Pilbara robot makes first iron ore delivery*. Accessed online at <http://www.thewest.com.au/>

<sup>9</sup> Mining Monthly. 2018. *Very large fleet now complete: The final vessel in Fortescue Metals Group's very large ore carrier fleet has arrived*. Accessed online at <http://www.miningmonthly.com.au/>



development in Western Australia, as the industry moves beyond the blunt instrument of billions of dollars of new mines and turns to the more specific toolkit enabled by technology and innovation.

**FIGURE 2.5** GLOBAL IRON ORE COST CURVE – COMPARISON OF 2013 AND 2017



SOURCE: ACIL ALLEN CONSULTING

# MRIWA RESEARCH CASE STUDIES

0001





### 3.1 Approach to case study quantification

Important aspects of ACIL Allen's approach to selecting and quantifying case studies for the purposes of this economic impact assessment are discussed below.

#### 3.1.1 Case study selection

Upon engagement, MRIWA requested ACIL Allen's frame of reference for the engagement centre as much as possible on projects that had been undertaken since the new Act had been active. This required ACIL Allen to carefully define the scope of the engagement, as the task of valuing the impact of research outcomes is a challenging one.

Since its inception, the MRIWA (and its pre-cursor body MERIWA) have funded over 350 individual research projects with a combined State funding contribution of at least \$35 million.<sup>10</sup> It is not technically feasible to assess each of these projects, for a combination of reasons, mostly centred on the notion that the application of the outcomes of research are likely to have become "business as usual" for the State's minerals producers over time if they are successful, and the researchers who undertook the research and/or companies that funded it may no longer be active in the industry.

In consultation with MRIWA, it was decided the economic impact assessment would centre on the quantification of forecast future realised benefits of research funded over the period 2018-19 to 2027-28. This "future focussed" economic impact assessment inherently involved the use of financial projections and modelling based on assumptions, which were derived via consultation with researchers and members of industry plus a review of research reports prepared by MRIWA funded researchers at the conclusion of research engagements.

This introduced an additional element of uncertainty into the assessment, as realisation of the benefits requires the research to translate into benefits. As a means of addressing this, ACIL Allen adopted the approach discussed in Section 1.1 quantifying a group of individual research projects that ultimately formed a "chain" or research program centred on the delivery of an overall benefit to the State's minerals industry. This was the approach taken for four of the six case studies assessed. The remaining two case studies selected were recent investments made to advance the commercialisation of specific technologies where the benefits were clear and identifiable.

ACIL Allen sought out research that had resulted or was likely to result in the development of a new technology or process that could be readily identified and applied by a minerals producer or explorer currently operating in Western Australia. This was a means of ensuring case studies selected had the best chance of being able to be quantified using real world information and data, as a means of

<sup>10</sup> MRIWA was able to provide disaggregated funding information for projects undertaken with an MRIWA/MERIWA project code of M236 or later (projects funded since approximately the 1994-95 financial year).

leaning against the uncertainty associated with the general approach of estimating the potential future benefits of MRIWA-funded research. By using real world information, the assessment is grounded in the current and expected future activities of the minerals industry.

In addition, acknowledging the fact the study was centred on understanding a limited number (six) of what is more than 350 MRIWA/MERIWA funded projects, ACIL Allen sought MRIWA's assistance to build a group of research programs that were considered the most prospective by way of benefits to the State. Projects selected ultimately reflect the MRIWA's Research Priority Plan, and address the application of new technologies or techniques in a range of the State's individual minerals industries.

Following this case study selection process, ACIL Allen and MRIWA agreed to centre the study on the assessment of the following six research program case studies.

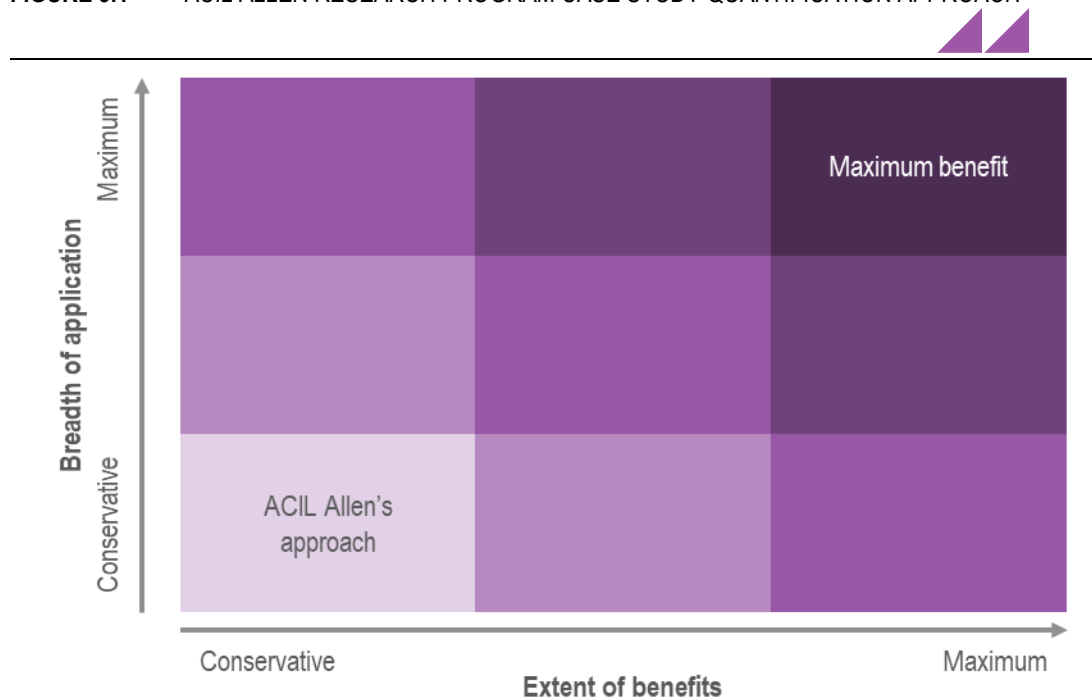
1. **Grade Engineering:** a group of four projects (with additional projects to come) co-funded by MRIWA and completed as part of the CRC ORE II program. Grade Engineering seeks to improve mine economics in a range of ways through the application of advanced and real-time mineral grade assessment techniques.
2. **Wearable Technologies for Safety:** a single project which saw the MRIWA co-fund with Roy Hill Holdings the commercial trial of a technology product that aims to reduce the incidence of avoidable musculoskeletal injuries – currently in mining but with application across industry.
3. **mXrap Platform:** a nine project, multi-decade research program centred on building a more informed understanding of the science of rockburst and rockfall events in underground hard rock mines. The research has ultimately culminated in the development of a software platform that is in operation across a number of mine sites around the world, which acts as both a real-time data capture and information platform.
4. **Gold Exploration Targeting:** a four project research program centred on building a better understanding of the Yilgarn Craton in the Eastern Goldfields region of Western Australia. The program has resulted in development of a new, data-based exploration screening approach which has worldwide application, and in the short term may lead to additional gold and precious metals discoveries in the target region.
5. **Standardisation of Leaching Risk Assessments for Environmental Impact Assessments:** a two project program with the ChemCentre (another WA Government statutory authority) centred on the development of a more time and cost effective approach to environmental leaching risk assessments for new mine proposals. The project will result in a standardised approach to apply initially across the State's iron ore mine environmental assessment approval processes, reducing the time taken to go through the EIA process.
6. **Coiled Tubing Drilling Fluid:** a single research project centred on solving a specific problem as part of the commercialisation process of the DET CRC's coiled tubing drill rig exploration technology.

The research programs are mapped against both the Research Priority Plan and the State's mineral commodity production in Section 3.2.

### 3.1.2 General quantification approach

Valuing the future application of research is an exercise driven by theories, projections and assumptions. Acknowledging this, ACIL Allen has taken a very conservative approach to the quantification of the benefits of the selected MRIWA research programs.

In a general sense, ACIL Allen has quantified a conservative, realistic application of the technology or approach developed as a result of each of the research programs. This means results should be interpreted as at the low end of what is possible, and should not be considered an assessment of the full scale of benefits that may arise as a result of the application of each technology or approach. This approach has been summarised below (**Figure 3.1**).

**FIGURE 3.1** ACIL ALLEN RESEARCH PROGRAM CASE STUDY QUANTIFICATION APPROACH

SOURCE: ACIL ALLEN CONSULTING

ACIL Allen has used publicly available information and data for companies or industries that are considered prospective users of the technology as the subject of each case study. This adds an additional layer of realism to the assessment, as the potential benefits are ground in what is currently happening in the State's minerals industry, and therefore represent a realistic projection of what could happen in the future. When quantifying the benefit, ACIL Allen has sought to calculate a change in a particular aspect of the operations of the entity or industry that is projected to benefit from the application of the technology or approach – such as a change in the average grade of a mineral extracted from source rock.

Finally, ACIL Allen has only quantified benefits which can be directly attributed to the application of the technology or approach. This approach has been taken to ensure the assessment is not overclaiming benefits. This is particularly important for the assessment of technologies which result in additional or more efficient exploration activities. These research programs are centred on enhancing the ability of the State's minerals sector to find more prospective resources and in turn create more mines. In ACIL Allen's view the development of a new mine is subject to a number of additional considerations beyond the scope of the application of a new technology or approach, and so it has not quantified these benefits. However, where a research program has a "find more resources" objective ACIL Allen has noted this and considered it in the qualitative component of the benefit cost assessment.

### 3.2 The six research program case studies

The six research program case studies selected for this economic impact assessment are presented below (Table 3.1).

**TABLE 3.1** MRIWA ECONOMIC IMPACT ASSESSMENT RESEARCH PROGRAMS

Research program and primary researcher	MRIWA projects	Total nominal MRIWA funding	Primary mineral	Research Priority Plan Area (P = Primary, S = Secondary)				
				Find More Resources	Expand the Mining Envelope	Increase Recoverable Value	Improve Productivity	Develop New Products & Markets
<b>Application of Grade Engineering to WA Mineral Producers</b> CRC ORE II	M485 M500 M503 M534	\$286,000*	Gold	S	S	P	S	
<b>Wearable Technologies for Safety</b> Soter Analytics	M498	\$25,000	Iron ore				P	S
<b>Rockburst Mitigation Technology</b> Australian Centre for Geomechanics	M328 M341 M355 M360 M366 M386 M406 M419	\$735,403^	Nickel				S	P
<b>Gold Exploration Targeting Technologies</b> CSIRO	M358 M377 M410 M452	\$1,063,000	Mineral exploration	P	S			
<b>Standardisation of Leaching Risk Assessments for Environmental Impact Assessments</b> ChemCentre	M432 M513	\$301,360	Iron ore				P	
<b>Coiled Tubing Drilling System Development</b> Deep Exploration Technologies CRC	M515	\$150,000	Mineral exploration	P			S	S

SOURCE: ACIL ALLEN CONSULTING

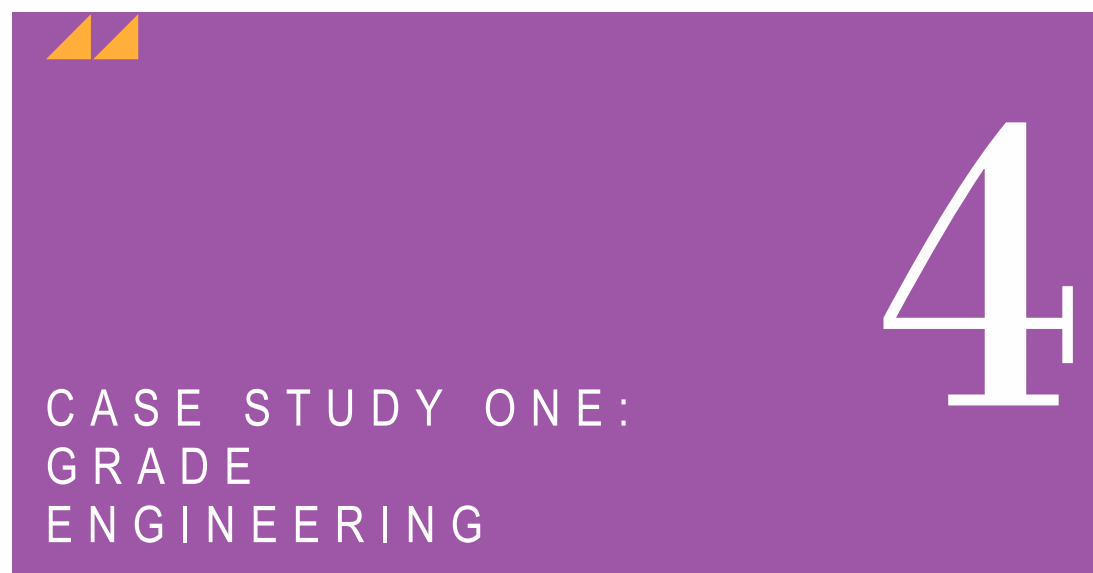
\*FUNDING FOR CRC ORE II TOTALS \$600,000 OVER SIX YEARS. THE VALUE LISTED AGAINST IT REFLECTS THE VALUE DISBURSED TO DATE

^MRIWA PROVIDED PROJECT COORDINATION SUPPORT FOR M386, WITHOUT A CONTRIBUTION TO PROJECT FUNDING

In addition to reflecting the MRIWA's Research Priority Plan and covering the State's major mineral producing industries (including exploration), the six selected case studies cover on other aspects of MRIWA's engagement with both the minerals sector and the research sector. These include:

- Two projects with Cooperative Research Centres (Grade Engineering and Coiled Tubing Drilling)
- Two projects with long research partnership histories (Rockburst Mitigation and Gold Exploration Targeting Technologies)
- Two projects targeted at a specific challenge in the commercialisation of a new technology (Soter Analytics and Coiled Tubing Drilling) which involved co-funding with the METS sector
- Projects involving universities versus projects directly engaging with the private sector

The next six chapters discuss each of the above research program case studies and ACIL Allen's assessment of the potential future benefits associated with the application of the technology or approach developed.



## 4.1 Research summary

One of MRIWA's most significant funding partners in recent times has been the CRC for Optimising Resource Extraction (CRCORE), which is now in its second iteration as a Commonwealth Research Council-funded research body. CRC ORE II's remit is to identify, integrate and implement innovation that delivers operational value to Australia's mining industry, centred on finding means and ways to reverse Australia's declining mining productivity.

CRC ORE II has 24 funding participants, of which the MRIWA is one. As with all CRCs, CRC ORE II is a funding leverage body, meaning it provides matched funding on certain terms. These arrangements are governed by the CRC's funding agreement, of which the MRIWA is a party. The agreement will see the MRIWA invest \$600,000 in research funding over the six year life of CRC ORE II, which will be leveraged into \$1.8 million in total research funding by the Commonwealth Government, State (through MRIWA) Government and industry participants.

One particular element of research the MRIWA has been a direct party to is so-called **Grade Engineering**. To date, the MRIWA has invested in four specific projects centred on this area of research, which are outlined below.

The four specific MRIWA projects are discussed below.

### 4.1.1 M485

*Project Title: GE.VIEW.WA – Developing New Tools and Resources for Benchmarking Grade Engineering® Opportunity for the WA Gold Mining Industry*

This project applied CRCORE's Grade Engineering lens to existing data in the WA Government's GIS platform GeoVIEW, to assess mining areas which may benefit from the application of Grade Engineering.

### 4.1.2 M500

*Project title: On-belt Gamma Activation Analysis (GAA) Sensing for Gold: Phase 2 (Buildable Prototype Design and Laboratory Testing of Components)*

A project to fund the development of a commercial scale prototype on-belt gold sensor to apply Grade Engineering approaches developed by CRC ORE II to the Western Australian gold industry.

#### 4.1.3 M503

##### *Integration of Enhanced Grade Engineering Grade by Size Gangue Liberation and More Energy Efficient Comminution*

This project aims to undertake extensive laboratory-based research into enhancing coarse liberation of minerals from waste materials through controlled energy application using technologies for a range of selected ores and operations.

#### 4.1.4 M534

##### *On-belt Gamma Activation Analysis (GAA) Sensing for Gold: Phase 3 (Preparation for Pilot Plant Campaign)*

A follow on from M500, this project extends the on-belt gold sensor technology to a higher level of technological readiness by developing a buildable design for a prototype on-belt gold sensing device.

#### 4.1.5 Funding summary

Collectively, these projects have received \$286,000 of MRIWA funding through its commitment to CRC ORE II, for a combined research project value of \$2.0m to date

## 4.2 The problem and solution

CRC ORE II has provided a summary of the application of grade engineering via its technical report associated with MRIWA Project M485. This has been reproduced below (**Box 4.1**).

During a consultation session, CRC ORE II provided a simple synopsis of the role of grade engineering and the way it may impact on the Western Australian mining industry.

According to CRCORE, around 99 per cent of the material used in the process of producing many base and precious metals (for example gold, silver, copper and nickel) is waste material with very low commercial value relative to the metal content of the material. The process of separating valuable metals from non-valuable waste materials is the most costly component of the mining process for base metals, as it requires repeated processing of the mined material to filter away the waste component. CRC ORE II suggested to ACIL Allen that the separation of waste materials constitutes 40-50 per cent of the cost of a typical base or precious metals operation.<sup>11</sup>

Grade Engineering can help address this problem in two ways.

At first, it allows for a more precise targeting of the most valuable source material across a mining area, giving miners and explorers better information to select areas for resource extraction. The current approach sees miners and explorers adopt an “averaging” approach over a tenement, whereas adopting the Grade Engineering approach allows for more precise resource volumes to be determined prior to mining. This can help reduce costs, both for explorers and miners, by allowing for a more efficient mining process. This was the focus of MRIWA Project M485.

Second, CRC ORE II is now seeking to develop and commercialise a real-time grade engineering technology solution that would allow producers of base and precious metals to better understand the precise minerology of their mined material at the point of processing. This would afford a miner information to better separate the most prospective and valuable material from the least prospective and valuable material, improving the efficiency of resource extraction. This aspect of the technology has been successfully trialled on the waste stockpile at a gold mine in Bolivia, with CRC ORE II indicating the ore discovered in what was formerly considered wholly waste material was valued at US\$1 billion.<sup>12</sup> The application of this technology is the focus of MRIWA Projects M500, M503 and M534.

CRC ORE II indicated to ACIL Allen this research is still in the trial phase, with a target date for commercialisation towards the end of the 2020-21 financial year. MRIWA Project M485 saw CRC

<sup>11</sup> CRCORE. 2018. *Consultation Session with ACIL Allen*, 31 July 2018.

<sup>12</sup> Adair, B. and D. King. 2017. *Presentation to International Mining and Resources Conference: Innovation in Action, A step change in the energy, production and water signatures at the MSC site in Bolivia*. Provided by CRCORE.



ORE II use Western Australia's GIS capability (through DMIRS) to initially identify sites where its Grade Engineering technology could be applied. This information was used to help screen candidate sites for the application of the technology. The remainder of the projects funded to date are seeking to trial the application of technology on a small scale with a view to proving the concept ahead of commercialisation over the next two years.

#### BOX 4.1 CRCORE: INTRODUCTION TO GRADE ENGINEERING

A focus on throughput as the main driver of revenue has led to a bulk average mentality with respect to in-situ cut-off grades. In many cases, average grades used to define bench or stope scale processing destination decisions such as mill, dump leach, waste, etc. include significant sub-volumes of material outside cut-off specifications. An averaging approach ignores potentially exploitable grade heterogeneity below the scale of minimum mining unit even though significant localised grade heterogeneity is a dominant characteristic of many base and metal deposit styles and ore types.

Localised grade heterogeneity is typically overlooked in favour of maximising extraction rates and loading efficiency. This is coupled with a desire to blend ROM and produce steady state feed in terms of grade and physical properties to optimise and maximise recovery of saleable product particularly in crush-grind-float operations. Grade Engineering® recognises that in many cases out of specification sub-volumes assigned to destinations based on bulk averages can be removed using efficient coarse separation techniques in the 'dig and deliver' interface. Coarse separation (~10-100mm) can be used on a range of particle size distributions ranging from ROM to SAG discharge (Bearman, 2013). The earlier this occurs in the conventional dig and deliver mining cycle the higher the potential net value of removing uneconomic material (Bamber et al, 2006 a and b, 2008).

Although there are examples of coarse pre-concentration generating value for some base and precious metal mining operations, there is no coherent system-based industry approach or standard methodology to assess optimal configurations for selecting specific technologies or equipment to deliver maximum value for specific ores and operational constraints. Grade Engineering® is the first large-scale initiative to focus on integrated methodologies to deliver maximum operational value (Pease et al, 2015).

SOURCE: CRC ORE II

## 4.3 The benefits

The potential benefits of Grade Engineering are presented below.

### 4.3.1 Quantified benefits

Grade Engineering is a technology which could be applied in a number of ways, and cuts across four of the MRIWA's five Research Priority Plan areas (it does not explicitly develop new products or markets). Given this potential scope, ACIL Allen has chosen to narrow down the application of the technology to two aspects of the Plan.

- **Expand the Mining Envelope.** The application of Grade Engineering could bring a larger area of a particular tenement or mining operation into scope for production, along the lines of the results of the full scale commercial trial in Bolivia.
- **Increase Recovered Value:** The application of Grade Engineering could assist existing and future miners to improve the resource recovered from their operations relative to what they would have been able to access in lieu of the technology.

To progress this case study, ACIL Allen has selected the gold industry as the potential users of this technology. This is because MRIWA Project M485 saw CRC ORE II identify a number of Western Australian gold mining operations as prospective for the use of Grade Engineering. Using production reports prepared by ASX-listed gold mining companies and data in the State's GIS system, ACIL Allen has calculated the potential improvements in resource recovery across three of the mining operations identified by M485 – the Edna May deposit (Evolution Mining), the DSO deposit (Regis Resources) and the Jundee deposit (Northern Star Resources). Combined, these three mines accounted for 7.6 per cent of Western Australia's gold production in 2016-17.

As the technology is still in the trial phase, it is assumed the benefits do not commence until 2020-21, meaning only eight of the ten years of the study period are available to derive a benefit.

Each mine was modelled as an individual entity applying Grade Engineering, with baseline production set at the production rate of the operation in the 2017-18 financial year and the mine operated until current commercial reserves were exhausted. To model the benefits, ACIL Allen increased the rate of gold recovery rate at each individual operation mine by one percentage point in each year of operation, and extended the peak production of the mine by one year.

As a result, each mine produces additional saleable gold, which manifests as a benefit in two ways: additional Gross Value Added for the mining industry, and additional royalty revenue for the State Government as a result of increased gold production. There is no change to the underlying cost structure of each operation assumed in the modelling as all that is changing is the rate of gold recovery from the application of Grade Engineering.

ACIL Allen estimates that the application of Grade Engineering in this way may result in a direct economic benefit to Western Australia of \$15.6 million over ten years, with \$1.4 million of this manifesting in additional gold royalties payable to the Western Australian Government.

#### **4.3.2 Non-quantified benefits**

The above is considered to be a very conservative assessment of the potential impact of the application of Grade Engineering to the Western Australian minerals sector, as the technique could be applied across most of the State's current and future base and precious metals production. The base of the quantification represents less than ten per cent of one precious metals industry in the State.

In addition, Grade Engineering could also be used as a way of bringing back into scope stranded assets which were not progressed due to sub-economic resource grades. This is because the technique results in an improvement to average resource grades via the targeting of the most prospective areas of a tenement, but more importantly can help lower average extraction costs by eliminating poorer quality material earlier in the mineral production process, improving project economics. The technique can also result in an extension of the current mine life of base and precious metals, a benefit which has been partially captured in the quantification process.

These non-quantified benefits are potentially an order of magnitude larger than the quantified benefits, particularly if the technique is able to contribute to the development of additional mines which otherwise would not have been deemed economic and so did not proceed to development.



## 5.1 Research summary

The Australian Centre for Geomechanics ('ACG') is one of MRIWA's longest running research partners, with the first MRIWA-funded ACG research project approved around the turn of the century. The ACG's research mission is firmly rooted in improving mine safety by studying the properties of underground hard rock mines and hard rock mining techniques, with a view to reducing the risk of harmful – and often fatal – instances of mine failure.

While a small component of Western Australia's mining sector due to the State's relative abundance of surface minerals, underground hard rock mining is a critical part of the global minerals industry. Underground hard rock mines typically involve the development of vast systems of man-made shafts and tunnels built to access resources. This kind of activity introduces a risk known as rock burst, where changes in the geomechanics of rocks which have been in place for thousands of years result in stress which leads to rock falls, collapses or explosions.

Through its long term partnership with MRIWA, the ACG has built a world leading research and applied technology capability in **rock burst mitigation**. The approach uses real time seismic information from mine sites to provide predictive analytics that can be used by mine engineers to either address rock burst risks as they arise or better structure underground mining systems so these risks don't occur. This has ultimately led to the development of a software platform managed by the ACG which acts as both a research dissemination tool and a real-time data capture program, with users providing the information about the seismicity of their mines in order to receive the analytics from the ACG.

The approach has been developed over a near-20 year research partnership between the ACG and MRIWA (and its precursor body), with eight individual research projects forming one major research program into the issue. These projects have also drawn significant financial support from industry partners in Western Australia, across Australia and around the world, highlighting the significance of the work and its breadth of application.

### 5.1.1 M328

*Project title: Mine Seismicity and Rockburst Mitigation Management*

The first project in this research program (which emerged over time), this MERIWA funded project centred on addressing mine seismicity and rockburst risk issues in Western Australian mines, where high stress conditions combine with localized strong rockmass conditions and aggressive mining strategies in some ore bodies. The approaches taken were technology transfer, training and applied research to better understand local problems, based partly on improving the management of seismic monitoring data.

### 5.1.2 M341

*Project title: Towards the Elimination of Rockfall Fatalities in Australian Mines*

This was a follow up study on the initial MERIWA-funded project, bringing additional mines into the reporting framework developed in M328. The result was the first attempt to develop a database of rockburst events in Western Australian mines. The study's key recommendation was the development of a standardised reporting approach that would create a dataset to allow for study of rockburst events.

### 5.1.3 M355

*Project title: Mine Seismicity and Rockburst Mitigation Management – Phase II*

This study continued development of the standardised approach to rockburst event reporting, and began the development of a real-time software platform that applied the findings of previous research to real-time seismic monitoring information at a number of mines. The result of the study was the precursor to mXrap, which was in use at 15 mines.

### 5.1.4 M360

*Project title: Australian Rockfall Research – Phase II*

This study was another in the series that advanced previous research, resulting in a database with 800 rockburst events and a systemic approach to understanding the nature and risks of these events in Australian mines. The report proposed a standardised methodology for assessing rockburst risks.

### 5.1.5 M366

*Project title: High Resolution Seismic Monitoring in Open Pit Mines*

This study took the findings of previous studies which centred on underground mine risks and applied it to deep (noting open pit mines were beginning to reach depths of >900m) open pit operations.

### 5.1.6 M386

*Project title: Broadening the Application of Seismic Monitoring in Australian Underground Mines*

This study was centred on developing a deep understanding of the seismicity of mines in the Kalgoorlie-Kambalda and Leinster regions in Western Australia, for analysis and eventual application in the ACG's emerging software platform.

### 5.1.7 M406

*Project title: Advancing the Strategic Use of Seismic Data in Mines*

This study was centred on developing a model of longer term seismic risks in underground mining operations, as well as the risks that result in larger rockburst issues occurring and the "caving process".

### 5.1.8 M419

*Project title: Advancing Rock Burst Mitigation Techniques*

The final study in this research program was centred on the completion of a number of individual areas of research in rockburst mitigation, including seismic hazard assessment, analysis of mining-induced seismic responses, cave tracking and support performance under dynamic loading. The project saw the finalisation of mXrap as it is currently constituted, which has become a tool used for real-time research and as a funding source for additional ACG research.

### 5.1.9 Funding summary

Collectively, these projects have received \$735,403 of MRIWA funding over the near-20 years of the research program, for a combined research project value of \$5.6m. The seven to one leverage ratio illustrates the value the minerals industry places in this research program.

## 5.2 The problem and the solution

All mining activities involve some element of risk. But underground hard rock mining is among the riskiest forms of mining, as it requires the development of large networks of man-made structures that disturb rock formations which had been otherwise stable for thousands of years. The deeper a mine, the more stress that is placed on the rocks.

During a consultation session, the ACG provided an overview of the kinds of risks and impacts of rockburst incidents in underground hard rock mines. The box below provides a summary of how rockburst incidents occur and the impact this can have on mining operations.

### BOX 5.1 ROCKBURST INCIDENTS IN UNDERGROUND MINES

Mining activity results in stress changes in the rock that may, under certain conditions, lead to violent failures taking place in the rock. When rock failure takes place in a violent manner, it radiates waves similar to what happens during an earthquake. These failure events are referred to as mining-induced seismicity, and can be thought of as small earthquakes caused or triggered by the mining stress changes. Sometimes these seismic events cause damage, in which case the damage associated with the seismic event is referred to as rockbursts.

SOURCE: THE AUSTRALIAN CENTRE FOR GEOMECHANICS

There have been four major rockburst-related mine incidents in Australia since the year 2000:

- Big Bell (2000): One person was killed and another injured in an underground rock fall at the Big Bell underground gold mine near Cue in Western Australia. The affected section of the mine had been closed for two months prior to the incident on account of safety concerns. The mine is now in care and maintenance.
- Beaconsfield (2006): The Beaconsfield underground gold mine collapsed in its entirety in 2006, resulting in one fatality. Two workers were trapped underground for two weeks following the incident. The mine has been closed since.
- Leinster (2009): The Leinster underground nickel mine in Western Australia has seen a number of seismic issues in its life, most recently in 2009 when a number of small earthquakes caused rockfalls in the mine. No workers lost their lives but the mine was closed intermittently, and has had similar issues in the years since.
- Cadia-Ridgeway (2018): The Cadia-Ridgeway underground and open pit gold operation in New South Wales experienced multiple tailings dam failures in 2018, following two small seismic events near the area around the operation. A year prior the underground portion of the mine was shut for three months after a more sizeable seismic event. No one was injured and no lives were lost.

Major rockburst incidents are relatively rare, but when they do occur the impact can be catastrophic, resulting in not just lost economic output but in the loss of human life. The ACG's research into rockburst mitigation techniques is centred on reducing the incidence of high cost rockburst events by providing real-time predictive analytics and other information that allows mining engineers to make better decisions regarding both the structure of new underground mines and means to address risks associated with operating mines.

As discussed in Section 5.1, the research program has culminated in the development of a software platform called mXrap, which is used around the world as a leading tool to address rockburst risks in underground hard rock mining. The ACG indicated to ACIL Allen during consultation that rockburst events cannot be eliminated, as the act of underground hard rock mining invariably leads to increased geological stress in rock formations. However, through its research and the mXrap platform the ACG

is contributing to the provision of information that allows for a reduction in the impact of incidents when they occur.

## 5.3 The benefits

The potential benefits of the ACG's mXrap platform and its research into rockburst mitigation techniques are presented below.

### 5.3.1 Quantified benefits

The ACG's mXrap platform is currently being applied across the world, with 52 companies using the software to manage seismic risks at their operations. There are an estimated 14 Western Australian mines currently using the platform, across predominately gold and nickel industries. ACIL Allen considers the research touches on two aspects of the MRIWA's Research Priority Plan:

- **Develop New Products and Markets:** The ACG's mXrap platform has resulted in the development of a new technology solution which is now applied to mines across the State and the rest of the world. The research has ultimately fostered the development of a mining technology export product, which ACIL Allen considers the primary channel of quantifiable benefit from the research.
- **Improve Productivity:** The ACG's mXrap platform provides mine engineers with the means to both better plan their mining activities and to respond to potential seismic events before they become significant issues – leading to risk events and mine closures.

Neither of these consider the real aim of the research, which is to improve mine safety and reduce the incidence of injury and fatalities as a result of seismic incidents in underground mines. ACIL Allen has discussed this in the non-quantified benefits section below.

To progress this case study, ACIL Allen completed two pieces of modelling. The first is the development of a simplified operating model of the mXrap business within the ACG centred on understanding its revenue, wages, non-wage operating expenditure and profitability. ACIL Allen modelled mXrap as a standalone business entity operating in Western Australia, delivering economic benefits to the State's economy that would not have occurred had the mXrap platform not been developed.

The ACG advised ACIL Allen that the mXrap business employs four full time equivalent staff and raises revenue of \$900,000 per annum through licencing the platform to companies around the world. Using publicly available benchmarks ACIL Allen estimated the rate of non-wage expenditure and profitability of an IT services firm in Western Australia. Based on this analysis, ACIL Allen estimates the mXrap platform results in a direct economic benefit to the State of \$0.6 million per annum, or \$5.7 million over the modelling period.

An additional benefit was modelled as a proxy measure for the productivity impact of avoided or deferred mine closures. As discussed in Section 5.2, Australia has experienced a major seismic event that has resulted in a mine closure once every ten years. The nature of these events is they are difficult to predict reliably – it is why the information provided by mXrap is so valuable to those who use it.

As a way of modelling the impact, ACIL Allen has gathered the production and cost information from a current user of mXrap from the company's 2017-18 annual report. It is assumed that a mine closure event would result in the loss of nine months of operations, resulting in lost production, wages and non-wage expenditure from the mine relative to if it had not closed. Based on feedback provided by the ACG during consultation, the analytics provided by mXrap will not prevent a mine closure event from happening, but they may reduce the incidence of them.

ACIL Allen has assumed that mXrap changes the incidence of a mine closure event from once every ten years to once every 12 years. To model the benefit, ACIL Allen has converted the cost of this mine closure event into an annual risk-adjusted saving, spreading the cost savings of a two year deferral of the hypothetical mine closure over each year of the study period. ACIL Allen estimates this aspect of the mXrap platform results in a direct economic benefit to the State of \$1.9 million per annum, or \$19.4 million over the modelling period.

### 5.3.2 Unquantified benefits

The nature of seismic events in the underground mining sector means it is difficult to predict with any sense of scale or certainty the potential economic loss resulting from a series of events over a period of time. It is possible that a number of events resulting in mine closures could occur over the ten year modelling period of this study; equally, it is possible that no events occur.

With respect to the cost of seismic events, the real objective of the research program is to reduce the human cost of rockfall and rockburst events in underground mining. As discussed in Section 5.2, there have been a number of underground mining events result in injuries and fatalities, which result in a material cost to society. The information provided by the mXrap platform is more targeted at the provision of information that would allow a mining engineer to be alert to risks and take actions like clearing out a mine shaft prior to the event occurring, which may result in avoided injury or death even though the seismic event will still occur.

The Australian Government's Statistical Value of a Life suggests in 2014 a human life has a statistical value of \$4.2 million (\$4.6 million in 2018). As such, if the risks associated with a seismic event causing human injury or death can be significantly reduced, the societal benefit is significantly larger than the State Government's investment even if just a single life is saved as a result of the platform.

In addition, the ongoing profits generated from mXrap are used by the ACG to fund ongoing research in its areas of interest, which has the potential to produce additional innovations in the area of mining geomechanics. This creates additional research funding leverage that came about because of the State's continued investment in the ACG and this research program.





## 6.1 Research summary

The MRIWA have provided Soter Analytics with research funding for a trial of their wearable safety technology ('The Soter System') at Roy Hill, a large iron ore mine in WA. The MRIWA have part-funded the project with Roy Hill who have contributed \$85,000 each to fund the commercial trial in 2017. The trial will form part of the commercialisation process for the Soter System and is an important phase for bringing the technology to the market.

The Soter System has been designed for workers who are subject to repetitive stress injury-risk occupations and uses real time data to predict when injuries will occur. The device can also be used to train workers about the most efficient and least risky ways of moving their body when completing tasks.

The research project comprised of two separate trials in 2017. During the first stage, data was collected from workers who wore sensors on their body. Using algorithms, the data on the types of movements and the intensity of their movements were used to identify certain risks. The risk of each movement was then quantified.

The second stage that occurred in late-2017 involved using the data to develop actionable insights that can warn a worker when they are at risk of injury. These insights can be delivered immediately to the worker when there is a risk of injury. The system also enables the organisation to monitor the entire workforce's risk of injury.

During stakeholder consultation, Soter Analytics advised ACIL Allen that if they had not been able to source funding from MRIWA for these commercial trials, the company would have possibly ceased its commercialisation push and may have closed.

The project that the MRIWA have directly been involved in is discussed below.

### 6.1.1 M498

*Project Title: Soter Analytics - Wearable Technologies for Safety*

This project applied Soter Analytics' wearable technology to capture raw movement data from mine site workers. The data is analysed to predict whether a worker is at an increased risk of experiencing an injury, especially an MSK injury.

### 6.1.2 Funding summary

The MRIWA matched Roy Hill Holdings in providing \$85,000 of funding to support a commercial trial of the Soter System at Roy Hill's iron ore mine site in Western Australia.



## 6.2 The problem and solution

Soter Analytics suggest that existing safety technology used in the mining industry doesn't do enough to reduce the incidence of preventable musculoskeletal ('MSK') injuries in the workplace, which can result in long time injuries to "mission-critical workers". MSK injuries refer to injuries that affect the body's structural foundations (like muscles and bones), where persons who receive an injury lose some kind of movement as a result of repetitive stress or risky movements that break down part of the MSK system.

Soter Analytics place a value of \$140bn on workplace MSK injuries which have been found to be the most common type of injury for a workforce.<sup>3</sup> Accordingly, the Department of Mines, Industry Regulation and Safety ('DMIRS') estimate that the cost of an average MSK lost time injury is over \$70,000 per injury. Approximately 1,400 LTIs (of 1+ day lost) occur in the mining industry per year. Additionally, 46 per cent of these injuries can be attributable to muscular stress.

Soter Analytics have therefore designed a technology that can keep workers safe, on the job and performing. The Soter System targets MSK related injuries.

Soter Analytics describe themselves as a "coaching and improvement company" that can solve MSK injuries and feed data back to the worker to allow them to make better decisions.<sup>3</sup> The wearable sensor technology is low cost and records data on body posture, body movement as well as temperature and noise risk.

The Soter System is most suitable for occupations that are subject to repetitive stress injuries. In these types of occupations, the technology can reduce the risk of injury by educating and training workers about the most efficient and low injury risk movements.

ACIL Allen have identified several costs that are likely to be associated with an MSK injury. These include the lost productivity when a worker gets injured (a lost shift), project delays because of an injury (time to replace the worker), higher insurance premiums, compensation costs, replacement wage costs, medical costs and increased paperwork requirements.

The potential benefits of the technology can include full labour productivity, fewer project delays and shorter shutdowns. Additionally, cost savings can arise from the reduced need of backup labour, a reduction in compensation payments and lower premiums. ACIL Allen has modelled these potential cost savings.

## 6.3 The benefits

The potential benefits of Soter Analytics SoterSpine technology are discussed below.

### 6.3.1 Quantified benefits

ACIL Allen has limited the scope of the benefits to the iron ore industry in WA because the commercial trial was at an iron ore mine in WA. It's important to note that the Soter System has the potential to be applied across the industrial workforce due to its applicability to repetitive stress movement occupations.

The improved productivity of the WA mining industry is one of the MRIWA's five research themes which is the most applicable for the introduction of the Soter System. Given this, ACIL Allen will focus on the cost savings associated with a reduction in MSK related LTIs in the iron ore industry of WA.

**Improved Productivity:** The application of the Soter System can reduce the occurrence of LTIs relating to MSK causes. Assuming the technology is effective in reducing the occurrence of MSK injuries, the reduction in LTIs has the potential to reduce lost shifts, compensation and the cost to compensate additional workers. The overall productivity gain will arise from the reduction in the cost of production.

To quantify the cost of MSK related injuries to the iron ore industry, data was collected for MSK related LTIs (1+ day lost), the average days lost per LTI incident, the average salary of a mine employee, the replacement wage cost and the value of iron ore output per operational worker in the State's mining industry. We assumed that the costs of an LTI injury include the wages paid to a

replacement worker, rehabilitation costs and lost productivity for one eight hour shift (as a proxy measure for lost real productivity, noting in reality the real productivity impact will vary).

ACIL Allen modelled the impact of a ten-percentage point reduction in the incidence of MSK related LTIs (with 1+ day lost), half of the figure at the low end of a range suggested by Soter Analytics (who advised in their trial the incidence of risky movements reduced by 70 per cent, leading to projections that the technology could reduce MSK injury incidence by 20 to 30 per cent). The benefit manifests in a number of ways, including:

- Elimination of rehabilitation costs
- Cost saving of a replacement worker that is not required
- Avoided lost productivity, both in terms of the previously injured staff members wage and the actual productivity impact (as proxy measured by the avoidance of the loss of eight hours of iron ore production)

ACIL Allen estimates the application of the wearable technology may result in a cost saving of approximately \$26.6 million to the iron ore industry over a ten year period, or \$2.7 million per annum. This saving is net of the costs of installation and operation of the system, the revenue of which is assumed to flow off shore on account of the structure of Soter Analytics.

### **6.3.2 Non-quantified benefits to MRIWA**

ACIL Allen has considered the non-quantifiable benefits that are likely to arise from the introduction of the Soter System. These benefits haven't been quantified due to the uncertainty of their impact. Specifically, it is uncertain with how a typical miner will allocate additional resources that may arise from improved productivity. In the economic impact assessment it is assumed the improved productivity results in additional capital income (ie profit) earned by the minerals industry.

In addition, the Soter System may be applicable to more than the iron ore industry in WA. If the Soter System proves to be effective in other mining sectors (such as gold mining) or other industrial sectors, the direct benefits of the technology for the WA mining industry are likely to be much greater than what we have determined.



## 7.1 Research summary

Western Australia has a rich history in the mining of gold and other precious metal ores, dating back to the time of colonisation and federation (see Chapter 2). Much of this activity has centred on the Goldfields-Esperance region, with Kalgoorlie and surrounding communities the major gold mining hub for the State.

One particular sub-region has never reached the same levels of prospectivity and production as the rest, the Eastern Goldfields region. The CSIRO and researchers at UWA have, with the assistance of the MRIWA (and its precursor body MERIWA) invested significant time and research funding into better understanding the geophysical properties of the eastern provinces of the Yilgarn Craton, a geological formation that makes up the largest part of Western Australia's geology.

The Yilgarn Craton extends across the highly productive Kalgoorlie and surrounding regions. The eastern area of the Goldfields region exhibits many similar characteristics to the productive region around Kalgoorlie, but to date has not been anywhere near as valuable to the State as previous studies suggest it should be.

As part of this research program, the CSIRO and its research partners have developed a new approach to exploration ventures for base and precious metals. The approach centres on the derivation and application of big data sets to assist in exploration targeting, which ultimately result in a need to do less drilling in order to get the same information as traditional approaches. This reduces the cost of an exploration venture, which either allows an explorer additional resources to increase the amount of exploration occurring, or to complete the same exploration but at a lower cost (potentially helping to improve the commerciality of discoveries).

To date, the MRIWA has invested just over \$1 million across four research projects which form this research program, with the total research program valued at \$3.2 million.

The four specific MRIWA/MERIWA projects are discussed below.

### 7.1.1 M358

*Project title: Scale-integrated, Architectural and Geodynamic Controls on Alteration and Geochemistry of Gold Systems in the Eastern Goldfields Province, Yilgarn Craton*

This project was the start of the research program, and centred on building an understanding of the underlying properties of the Eastern Goldfields Province of the Yilgarn Craton. This was the start of the development of the approach of understanding the full extent of a mineral system as a means of better targeting exploration activities.

### 7.1.2 M377

*Project title: Scale-integrated, Architecturally, Geodynamically & Geochemically Constrained Targeting Models for Gold Deposits in the Eastern Goldfields Province, Yilgarn Craton*

This project built on the findings of the first MERIWA-funded project, but included an additional predictive analysis which sought to understand the most prospective areas for gold exploration in the region based on taking a systems approach. A key outcome of this work is the recognition that gold deposits are related to chemical gradients that may be mapped in terms of variations in alteration mineralogy, mineral compositions or element abundances – meaning higher level information regarding the mineralogy of a deposit can be used to accurately predict resource location.

### 7.1.3 M410

*Project title: High Grade Gold Deposits: Process to Prediction*

This project was a field-based study applying the techniques developed in the first two phases of work to a series of brown field sites in Western Australia. The project documented the chemical and geological characteristics which were best able to predict the future location of gold deposits.

### 7.1.4 M452

*Project title: Pathways to High Grade Gold – 3D gradient mapping of mineral systems*

The final project in this research program saw the CSIRO apply 3D mapping techniques as an additional tool to help contextualise and enhance the sorts of information regarding gold mineralogy in new and existing operations. Like the previous study, the emphasis was on application and technology transfer, which saw the CSIRO work with a number of Western Australian-based gold producers as a means of advancing its approach.

### 7.1.5 Funding summary

To date, the four research projects that make up this research program have seen the State invest \$1.06 million, and result in leverage of an additional \$2.2 million in Commonwealth and industry partner research funding.

## 7.2 The problem and the solution

Western Australia has historically been a major producer of refined gold. Much of this production has centred on the Goldfields-Esperance region to the east of Perth. In 2017-18, the Department of Mines, Industry Safety and Regulation found producers in the region produced 65 per cent (\$7.5 billion) of the State's total gold production by value, which is around five times the share of the second largest gold producing region (Peel, \$1.5 billion). This is a trend which has held for some time, with mines in the Goldfields-Esperance region producing 168 million ounces of the State's total estimated cumulative gold production of 254.8 million ounces.

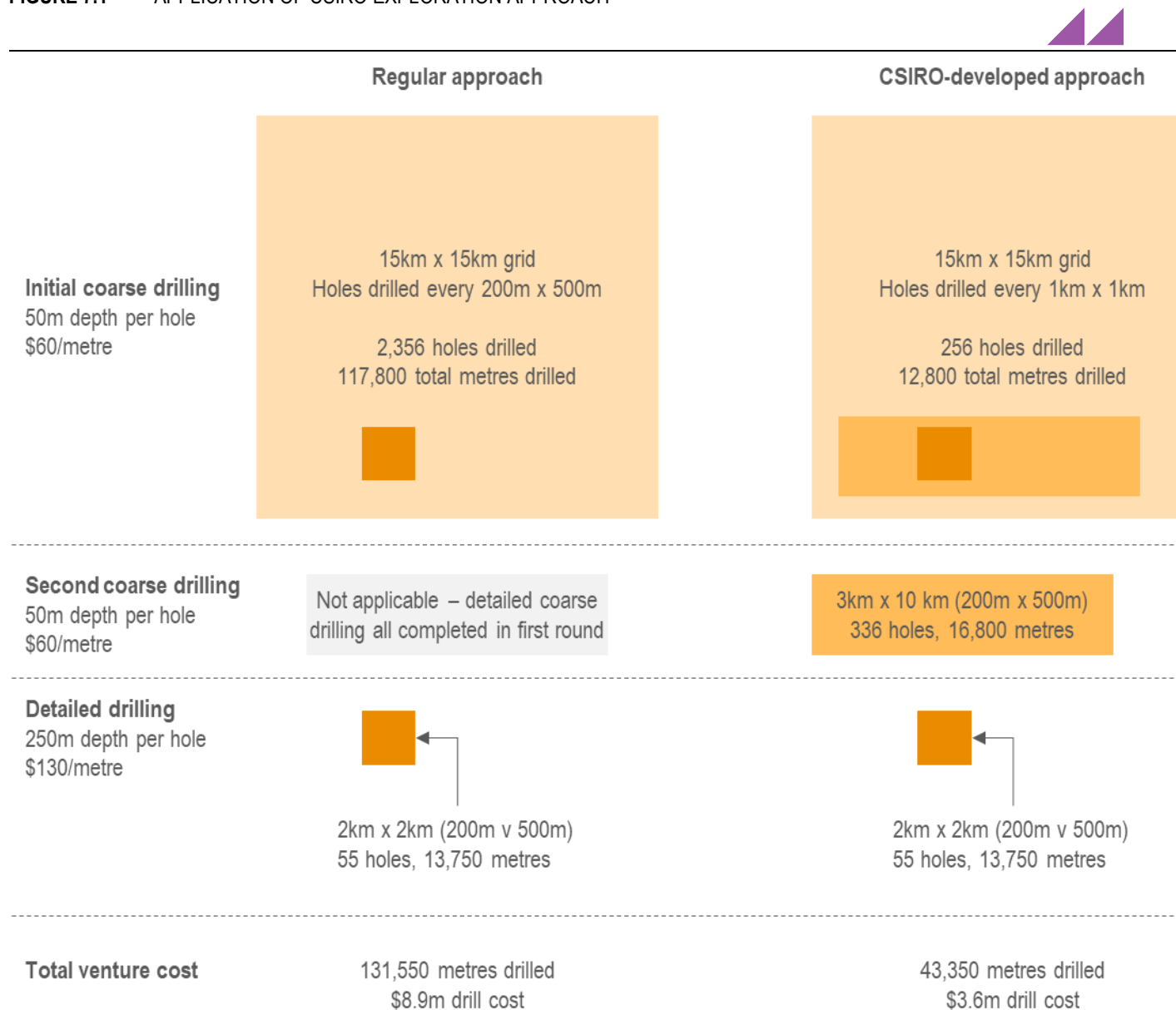
However, the eastern edge of the region has not been as productive as its underlying geology suggests it could or should be. This has led the CSIRO (and UWA for two of the earlier projects in the program) to invest research time and dollars into the development of a new approach to exploring the region. The approach centres on an understanding of the entire underlying geology of a particular geological formation, and building predictive analytics which can identify the most prospective areas for targeted exploration activities.

This is a significant change on the traditional approach to exploration, which is centred on “pulling out individual rocks and assessing them and hoping for the best”.<sup>13</sup> The application of a data-centric approach eliminates the need for so-called “coarse” drilling programs that are used as a first pass in an exploration venture to then better target more detailed drilling programs. An additional aspect of the research is it centres on understanding the basic chemistry of the region, rather than just the actual geology (which is also the typical approach).

<sup>13</sup> CSIRO. 2018. *Notes from ACIL Allen consultation session, 8 August 2018.*

The CSIRO provided ACIL Allen with a worked example of the application of the initial data-based screening and what it means for a typical exploration venture (**Figure 7.1**).

**FIGURE 7.1** APPLICATION OF CSIRO EXPLORATION APPROACH



SOURCE: ACIL ALLEN CONSULTING, BASED ON CSIRO (LIGHT ORANGE = INITIAL DRILLING AREA WITH COARSE DRILLING UNDER CSIRO APPROACH AND DETAILED DRILLING UNDER REGULAR APPROACH. MEDIUM ORANGE = PROSPECTIVE AREA IDENTIFIED BY CSIRO APPROACH BUT WHICH ISN'T IDENTIFIED AS PART OF TRADITIONAL DRILLING CAMPAIGN AS THE GRANULAR DRILLING OCCURS AT THE FIRST STAGE; DARK ORANGE = MOST PROSPECTIVE AREA WHICH IS DRILLED TO THE SAME EXTENT IN BOTH SCENARIOS)

According to the analysis, the CSIRO's data-driven exploration approach could result in a 60 per cent reduction in the cost of drilling in a typical exploration venture in regions where its database is available. This benefit can manifest in two ways: a reduction in the average cost of an exploration venture, or an increase in the amount of drilling undertaken for a given exploration budget.

The CSIRO indicated it plans to commercialise its approach to exploration over the coming years, partnering with potential users of information as a way to build up data sets, analyse them and provide insights to assist users in targeting their exploration activity.

### 7.3 The benefits

The potential benefits of the CSIRO's approach to exploration are presented below.

### 7.3.1 Quantified benefits

The CSIRO's approach to exploration is in the trial phase, but is currently in use by a number of companies operating in and exploring the Yilgarn Craton in the eastern Goldfields. ACIL Allen considers the research touches on two aspects of the MRIWA's Research Priority Plan:

- **Find More Resources:** The CSIRO's approach is ultimately centred on increasing the rate of discovery of gold in the eastern Goldfields region – and eventually across other regions. It contributes to this qualitatively by providing additional information to allow for better exploration targeting, and by reducing the cost of drilling which can lead to increased exploration activity.
- **Expand the Mining Envelope:** The CSIRO's approach can also contribute to expanding the envelope of existing mines by providing brownfield exploration information in a more cost-effective manner.

As discussed in Section 3.1, ACIL Allen has excluded the consideration of the potential impact of the discovery of additional resources, as it considers the act of finding a resource does not fully explain why a mining project develops. However, ACIL Allen has developed a means of quantifying the benefit centred on an understanding that a reduction in drilling costs may lead to an increase in overall exploration activity.

The CSIRO's own estimates suggest the application of its approach can lead to a 60 per cent reduction in exploration venture drilling costs. Using an estimate of the share of overall exploration expenditure owing to drilling, and additional assumptions regarding the composition of non-drilling expenditure on a typical exploration venture, ACIL Allen has estimated the potential impact of a reduction in drilling costs on the value of non-drilling expenditure.

The central assumption is that a typical minerals company determines its volume of minerals exploration on the basis of a budget constraint, and that any change in the cost of an exploration venture would see the company adjust its level of activity to meet that budget constraint. The CSIRO provided endorsement of this assumption for the purposes of modelling the benefit of its research program in this way, noting the decisions of a minerals company will vary on a case by case basis.

ACIL Allen used the 2017-18 actual exploration expenditure of two companies involved in the CSIRO's research program, and forecast how this would change on the basis of a simple linear regression analysis of the change in exploration expenditure against forecast future gold production (forecast compiled from the Office of the Chief Economist). This yielded an estimate of the future exploration expenditure of these two companies.

It is assumed the CSIRO's approach will become available for more widespread application in the 2020-21 financial year onwards. As a result, the benefit modelling is only applicable for eight years of the study period.

In determining the composition of this exploration spend, ACIL Allen relied upon an estimate prepared by the CSIRO in its research report for project M373,<sup>14</sup> and data from IBISWorld regarding the wage and services expenditure in a typical exploration dollar.<sup>15</sup> This suggested a typical exploration venture spent 38 per cent of its budget on direct drilling costs, 33 per cent on support services, and 29 per cent on direct labour.

To calculate the benefit of the approach, ACIL Allen applied the above ratios to the baseline estimates exploration expenditure to determine the share of forecast exploration expenditure required on drilling, support services and direct labour costs. To develop the shock, ACIL Allen reduced the value of drilling costs, and increased the overall level of exploration activity by an amount that would result in the total forecast exploration costs. This results in an increase in support services and direct labour expenditure over and above the baseline, creating a direct benefit in the form of increased spending in the mining support services sector and increased labour income paid to those working on the exploration ventures.

Critically, the reduction in drilling expenditure as a share of total spending does not result in any reduction in actual economic activity, as the drilling costs are assumed to mostly related to depreciation of drill rigs.

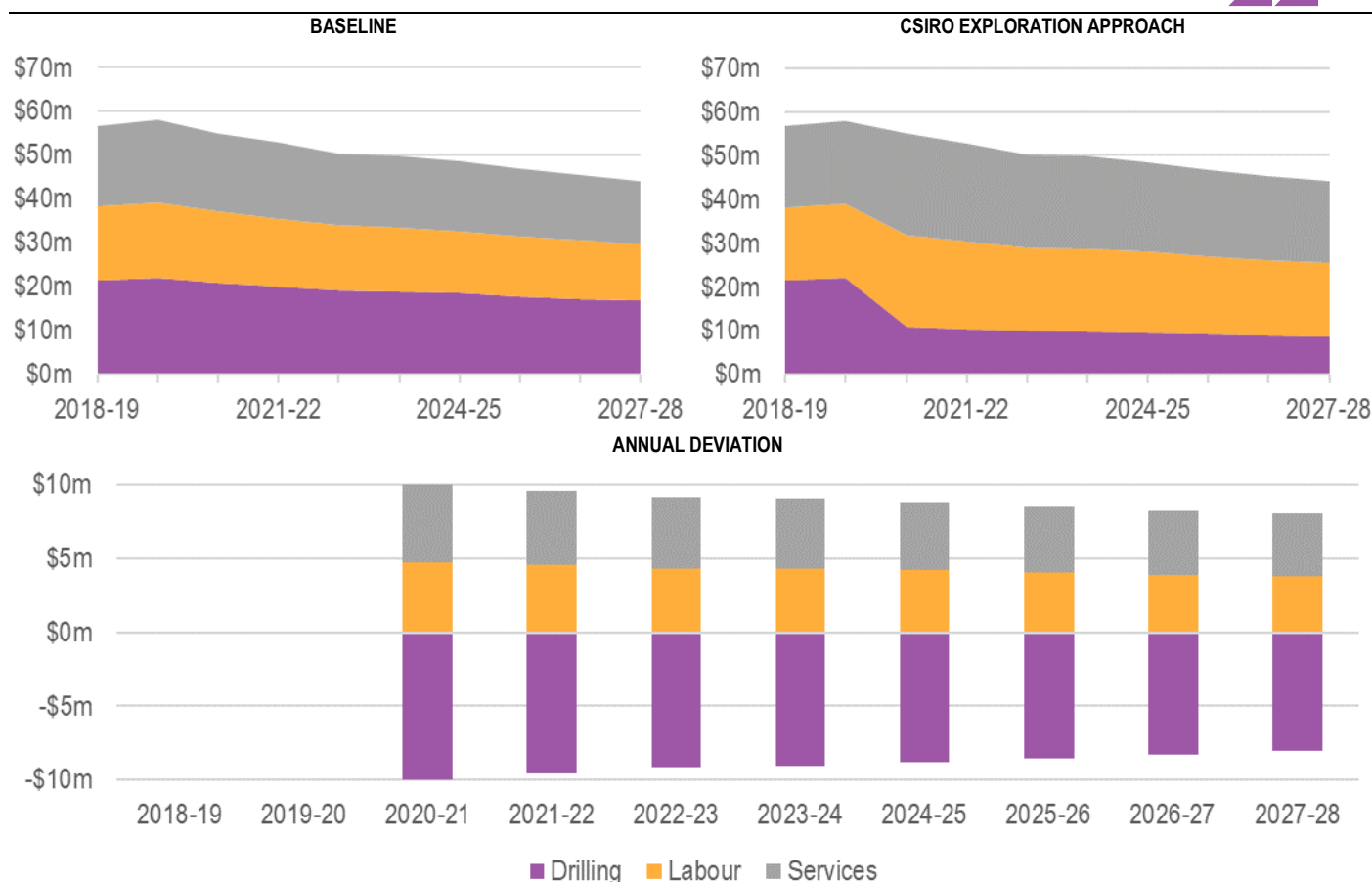
<sup>14</sup> CSIRO. 2008. *Development and Implementation of Advanced Automated Core Logging Technology for Enhanced Mine Feasibility and Development in Western Australia*. Accessed online at <http://www.mriwa.gov.au/>

<sup>15</sup> IBISWorld. 2018. *Australia's Mineral Exploration Sector, Industry Benchmark Report*. Accessed online at <http://www.ibisworld.com.au/>



Given this is a technical process, ACIL Allen has reproduced the shock in full below (**Figure 7.2**).

**FIGURE 7.2** CSIRO EXPLORATION APPROACH DIRECT SHOCK, EXPLORATION EXPENDITURE OF APPLICABLE COMPANIES, BY TYPE OF SPEND AND YEAR, \$M



SOURCE: ACIL ALLEN CONSULTING

ACIL Allen estimates that the application of the CSIRO's exploration approach may result in a direct economic benefit to Western Australia of \$71.4 million over ten years.

### 7.3.2 Unquantified benefits

The benefit modelled above is abstract, but reflects one of the mechanisms by which a change in the economics of an exploration venture can impact on the economy. However, the primary opportunity created by the application of this approach is to both better target existing exploration expenditure and to increase the amount of exploration activity undertaken in the State.

All things being equal, these impact channels should result in additional resource discoveries, which in turn would lead to an increased prospect of new mines progressing to development. The extent of the MRIWA's contribution to this research – \$1,063,000 in funding over four projects, the largest of the research programs in this study – reflects this potential.

In addition, the CSIRO indicated it was investigating the potential commercialisation of this technology as it further develops and is applied across the eastern Goldfields region over the coming five years. This would deliver additional economic benefits of a similar nature to those discussed in relation to the ACG's mXrap platform (see Section 5).



# CASE STUDY FIVE: STANDARDISED LEECHING ASSESSMENT TECHNOLOGIES

# 8

## 8.1 Research summary

The MRIWA has partnered with ChemCentre in a two-phase research project (M432 followed by M513) which aimed to validate and standardise an ‘*Accelerated Sequential Leaching Risk Assessment*’ (ASLRA). The ASLRA is designed to form part of the WA Government’s Environmental Impact Assessment (EIA) process to identify environmental contamination risks associated with new mines. The focus of the project is applicable to iron ore mining and its impact on ground and surface water resources. The first project (M432) aims to develop the technique and the second (M513) aims to roll out the technique to a larger number of funders.

The key advantage of the ASLRA is that it’s a fast process and can be used to prioritise long-term studies, to understand potential contamination risks earlier in the process and therefore improve the EIA process. Following ChemCentre’s discussion with industry and WA regulatory authorities, the consensus view is that:

*“existing chemical and mineralogical methodologies used to characterise mine wastes and to predict the long-term impact of mining on ground and surface water are unfit for purpose” (Black et al. 2017).*

The MRIWA provided a total of \$301,360 in funding across the two research projects. Funding was used to assist in the de-risking of the project from an industry point of view, and to provide financial support to ChemCentre. During phase-two of the research (M513) funding was used to validate the potential of the ASLRA as an applied technology.

Other sponsors of the research projects include CRC CARE, MRIWA, DWER and industry leaders such as Rio Tinto, BHP Billiton, FMG Group and Roy Hill. ACIL Allen is of the understanding that ChemCentre wouldn’t have had the means to fund the project without the MRIWA’s participation, nor would it have necessarily investigated the technology given its very broad remit as the State Government’s chemistry advisor.

### 8.1.1 M432

*Project Title: Validation and Standardisation of Sequential Leaching Tests to Better Predict the Impact of Mining on Ground and Surface Water Quality.*

The main aim of this investigation was to research, develop and validate accelerated sequential leaching methodologies as a tool to better identify contamination risks or iron ore mining to ground and surface water quality.



### 8.1.2 M513

*M513 Extension to M432 -Validation & Standardisation of Sequential Leaching Tests to Better Predict the Impact of Mining on Ground & Surface Water Quality.*

This project extension is to validate the application of the ASLRA using more samples of varying rock types. This will also satisfy regulatory and industry requirements.

### 8.1.3 Funding summary

The MRIWA provided a total of \$301,360 in funding across the two research projects. This funding was used to assist in the de-risking of the project from an industry point of view, and to provide financial support to the ChemCentre.

## 8.2 The problem and solution

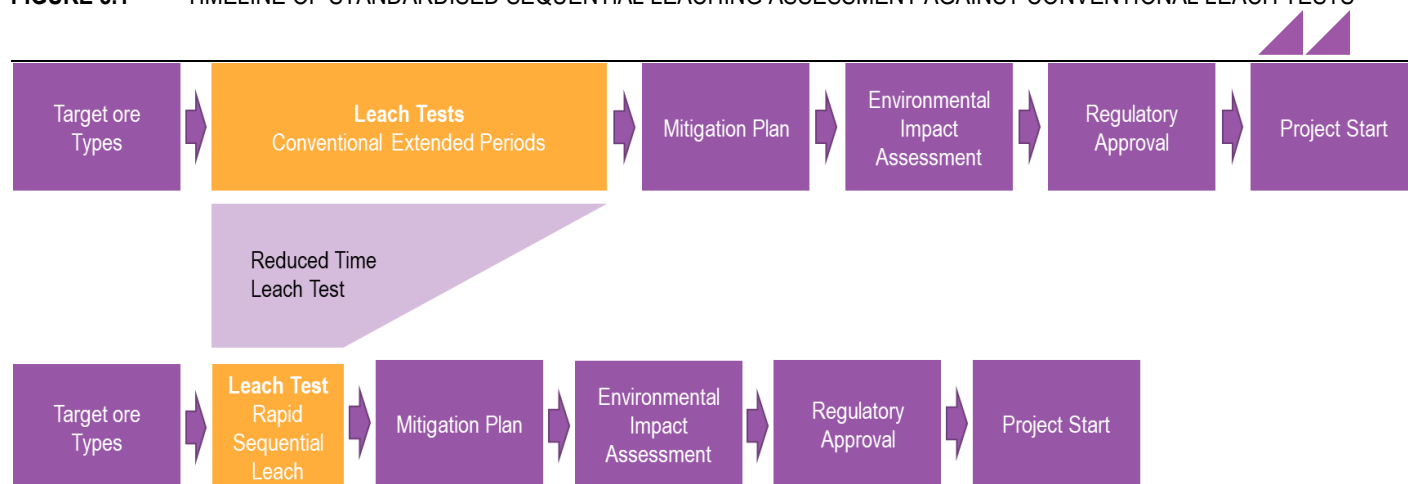
The problem with the existing study (Kinetic Leaching) used to predict the environmental impact of mining on ground and surface water quality is that they can take up to 2 years to complete. The consensus view of industry is that methods used to assess the impact of mining on ground and surface water quality is that they're "unfit for purpose" and delay the EIA process.

The proposed solution to the problem is to introduce an ASLRA. This test uses more aggressive solvents to screen and predict the impact on ground and surface water. The key advantage of the methodologies is that they are quick. The solvents are used to identify the order of metal extraction through time that may lead to the contamination of ground and surface water.

The early identification of these risk factors can help improve the EIA process and prioritise long-term kinetic leaching studies to validate potential contaminants of concern. In relation to an applicable mine site, the new testing method can improve:

- the waste and risk management process
- mine site closure planning
- whole of life mining operational costs
- the early identification of risks and better informed EIAs
- faster methods for predicting the impact of mining operations of water resources
- early acquisition of data that allows EIAs to proceed and be approved, and
- potential for mining to commence earlier

These are the key productivity improvements that can lead to a reduction in the operational costs of a mine site. A summary of the application of the accelerated sequential leaching methodology has been reproduced below (**Figure 8.1**).

**FIGURE 8.1** TIMELINE OF STANDARDISED SEQUENTIAL LEACHING ASSESSMENT AGAINST CONVENTIONAL LEACH TESTS

SOURCE: ACIL ALLEN, MRIWA, BLACK ET AL. 2017

## 8.3 The benefits

The potential benefits of the application of the standardised leaching assessment process and platform are discussed below.

### 8.3.1 Quantified benefits

To assess the benefits associated with the research projects, ACIL Allen focused on the improved productivity of the EIA process arising from the introduction of the standardised assessment. The new assessment is a rapid process and can also prioritise long-term and subsequent studies which can be expensive.

There are two potential options for the quantification of the impact of this project:

1. A reduction in the operating cost of the State's major iron ore miners (the current mineral group this technique has been applied to), which could manifest as an increased profit margin or additional non-EIA spending, or lead to an earlier production start date for the mine under assessment.
2. A reduction in the cost of the State Government's environmental approvals function, owing to the reduced need to inquire and assess the applications for mining licenses by the mining industry.

ACIL Allen selected the second option as a means to quantify the potential benefits of the productivity improvements in the EIA process, as the benefit is more tangible and predictable. ACIL Allen assumed that the EPA will require two less employees on an average employee cost basis and will therefore reduce their total cost of service per year. To derive the benefit, ACIL Allen has assumed a reduction in the headcount of the EIA function of the EPA leads to a reduction in the agency's total cost of services (\$9.4 million in 2017-18) equivalent to the share of the workforce (48 FTE) that is reduced (4.2 per cent). The benefit is modelled as an annual deviation over a nine year period, reflecting that the technology is expected to be rolled out in the 2019-20 financial year.

ACIL Allen estimates the application of the ASLRA results in a benefit to the State Government of \$3.5 million over the nine years the benefit is applicable, or \$0.4 million per annum.

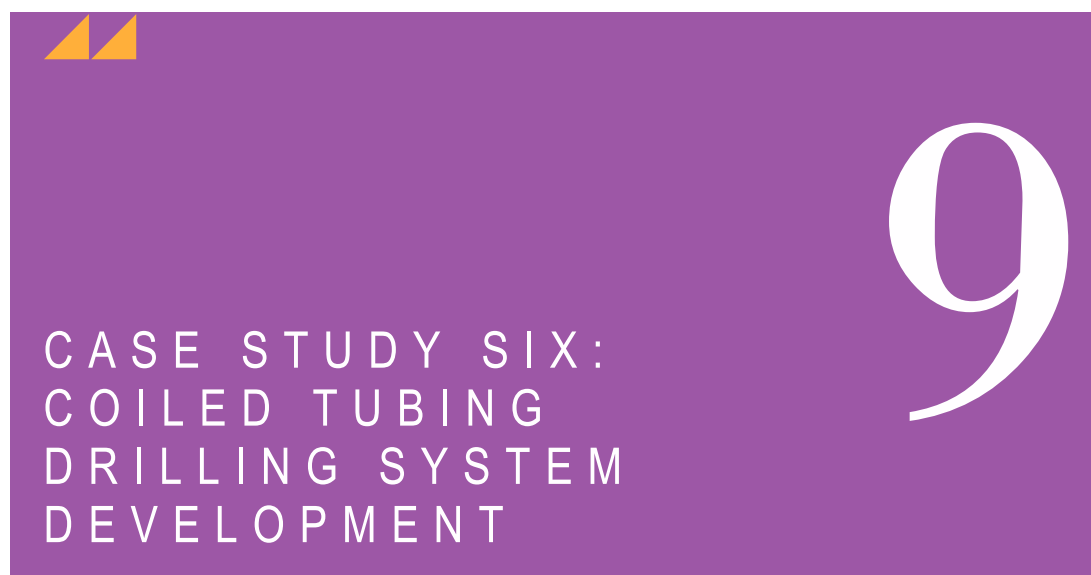
### 8.3.2 Non-quantified benefits

ACIL Allen has also considered the non-quantifiable benefits that may arise from the introduction of the standardised sequential leaching approach. Specifically, uncertainty surrounds how and if the miners will allocate additional resources that may arise from their improved productivity and cost savings. The new approach will reduce the burden and time costs associated with EIAs for miners.

- **Expanding the Mining Envelope.** The improved productivity of a mine and the cost savings from a reduced burden of EIAs may lead to additional spending on new technology that can enable the

mining of more challenging ore bodies. It is uncertain whether the mine will engage in this additional spending. Therefore, this potential benefit of 'expanding the mining envelope' hasn't been quantified.

- **Find More Resources.** If miners can reduce their cost of production and burden of EIAs, there is potential to allocate more resources to exploration and drilling activities. It is uncertain whether the mine will engage in this additional spending.
- **Application to Other Industries.** Research project M432 is applicable to the iron ore industry. The sequential leaching methodologies may also be applicable as screening tools for other base metal deposits such as chromium, manganese, nickel and cobalt. If applicable, there could be further productivity gains.



## 9.1 Research summary

The DET CRC was established in 2010 to develop cheaper, faster and safer ways of mineral discovery in Australia. The DET CRC's main challenge is in relation to Australia's declining inventory of resources and the increasing costs of exploration due to low exploration success<sup>3</sup>. One such project initiated by the DET CRC is the Coiled Tube (CT) drilling system.

The MRIWA has partnered with MinEx CRC (formerly DET CRC) and Curtin University to fund the next stage of development for the CT Drilling System in an aim to improve the productivity of exploration drilling in Western Australia. The research project is taking place at Curtin University and is estimated to be completed in April 2019.

The MRIWA provided \$400,000 towards the project (M515) which was mainly used to solve specific challenges associated with the development of the CT Drilling System. The MRIWA funding was also used to keep the technology development lifecycle moving after the initial DET CRC funding ran out. The MRIWA's funding has also meant the technology has been trialled in Western Australia as opposed to South Australia or Queensland.

The research project (M515) builds on the work done by DET CRC (now MinEx CRC) and in conjunction with Curtin University aims to:

- identify fluids that suit the system
- manage the loop of fluid down the drill hole
- determine the fluid recycling process, and
- automate the drilling process

The CT drilling system differs from conventional drilling in that it comprises of a continuous, steel coil instead of individual drill rods. CRC suggest that the CT Drilling System can achieve a cost of \$50 per metre in Greenfield mineral exploration drilling and has the potential to save \$140m in Australia by replacing Diamond Drilling (which costs between \$150 and \$300 per metre on an all-in basis depending on the phase of exploration). These cost savings can be directed to additional metres of exploration drilling and provide additional benefits to the mining industry.

The CT Drilling System is estimated to be 1/6<sup>th</sup> the cost of diamond drilling and 1/3<sup>rd</sup> the cost of reverse circulating drilling<sup>3</sup>. There is also no need to replace drill bits as the hole deepens which makes it a faster process. The CT Drilling System is also environmentally friendlier and safer compared to traditional diamond drilling.

CRC estimate that the CT Drilling System will be commercially available in the next two years.

### 9.1.1 M515

*Project Title: DET CRC Coiled Tube Drilling System Development*

Research project M515 is an important step for validating the CT Drilling System. The study is set to take place at Curtin University's school of Petroleum and Chemical Engineering and is due to be complete in April 2019.

### 9.1.2 Funding summary

The MRIWA have provided approximately \$400,000. The CT Drilling System has received approximately \$10m over the life of the CRC. The importance of the MRIWA's funding is that it went towards overcoming specific problems with the CT Drilling System. The funding has therefore played an important role in the commercialisation of the technology.

## 9.2 The problem and solution

The existing problem with exploration drilling (as per DET CRC) is the high cost and low discovery rate of traditional diamond drilling. This means that the risk of drilling can be relatively high compared to the reward of finding a mineral reserve. This is an ongoing issue faced in Greenfield exploration.

DET CRC believe that CT drilling can replace about 50 per cent of diamond drilling that occurs in Australia. The cost of diamond drilling used for exploration can be as much as \$400 per metre<sup>2</sup>. The CT Drilling System can achieve a cost of \$50 per metre<sup>3</sup>. The main cost savings arise from a reduction in manual operation which makes the process quicker.

Additional issues with traditional mining exploration and diamond drilling is the high injury rate due to drill handling and manual intensity. The CT Drilling System avoids this issue because it is a continuous system that doesn't require manual intervention to replace insert, touch or remove drills.

The CT Drilling System is also more environmentally friendly as it recycles water instead of pumping it into a separately drilled sump. Traditional mines pump water into a sump which can result in ground leaching problems.

## 9.3 The benefits

As per the MRIWA's Research Priority Plan's (RPP) five key research themes, there is one clear theme that relates to the introduction of the CT Drilling System. That is "find more resources".

ACIL Allen has considered additional exploration activity and the potential for new discoveries (and new mines) out of scope under its quantification framework. This is because ACIL Allen does not consider the fact additional resources are found as a sufficient condition to result in additional mines.

The CT Drilling System is designed to cut exploration drilling costs significantly. CRC estimate that there could be cost savings of up to \$140m to Australian miners who would then spend additionally on exploration ventures. This may lead to additional mineral discovery of more resources as well as employment income. CRC estimate these additional explorations to result in 2.5 moderate sized mineral discoveries to be unearthed per annum which would result in an NPV of \$200m. This demonstrates the potential scale of the benefit.

As such, there are no quantified benefits associated with this research program. However, ACIL Allen considers the MRIWA's funding is a relatively small amount in comparison to the lifetime potential of the project given the significant impact on exploration economics. In addition, the MRIWA's role in the program was to address specific challenges that the CT Drilling System faces and has therefore played an important role in contributing to the commercialisation process.

# 10

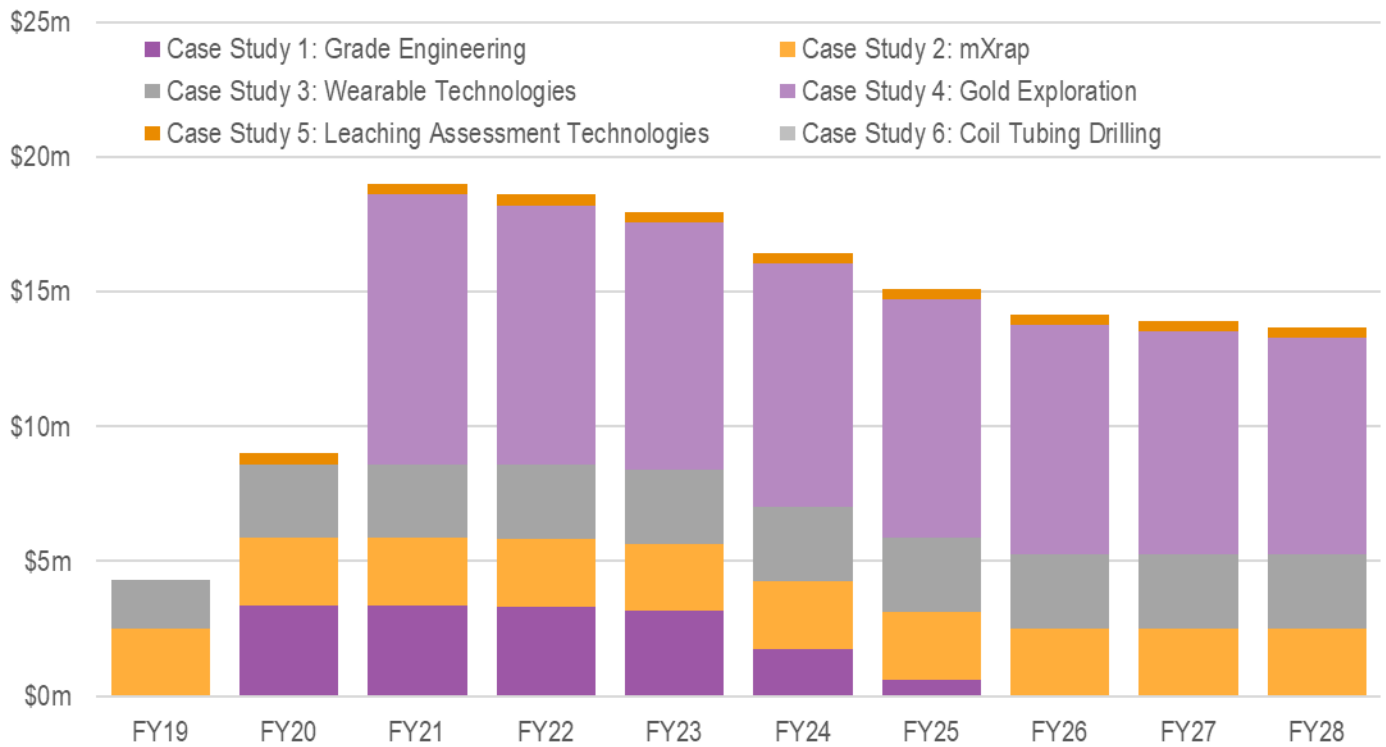
## RESEARCH CASE STUDIES: SUMMARY

### 10.1 Quantification summary

#### 10.1.1 Overall benefits summary

Overall, the quantified benefits of the six research program case studies selected for analysis total \$142.2 million over the ten years 2018-19 to 2027-28 in real (2017-18) dollars, or approximately \$14.2 million per annum. The estimated annual benefits sorted by research program case study are presented below (**Figure 10.1**).

**FIGURE 10.1** DIRECT BENEFITS OF RESEARCH PROGRAM CASE STUDIES, REAL 2017-18 DOLLARS, \$M



SOURCE: ACIL ALLEN CONSULTING

The largest modelled benefit accrues as a result of Case Study 4 (CSIRO's Gold Exploration Technology research program), while Case Study 6 (DET CRC's Coil Tubing Drilling research program) does not produce any quantified benefits in this framework. This schedule of real benefits is the input into ACIL Allen's CGE model framework and are used to estimate the overall direct and indirect economic benefits of the combined research program case studies to Western Australia (see Section 11).

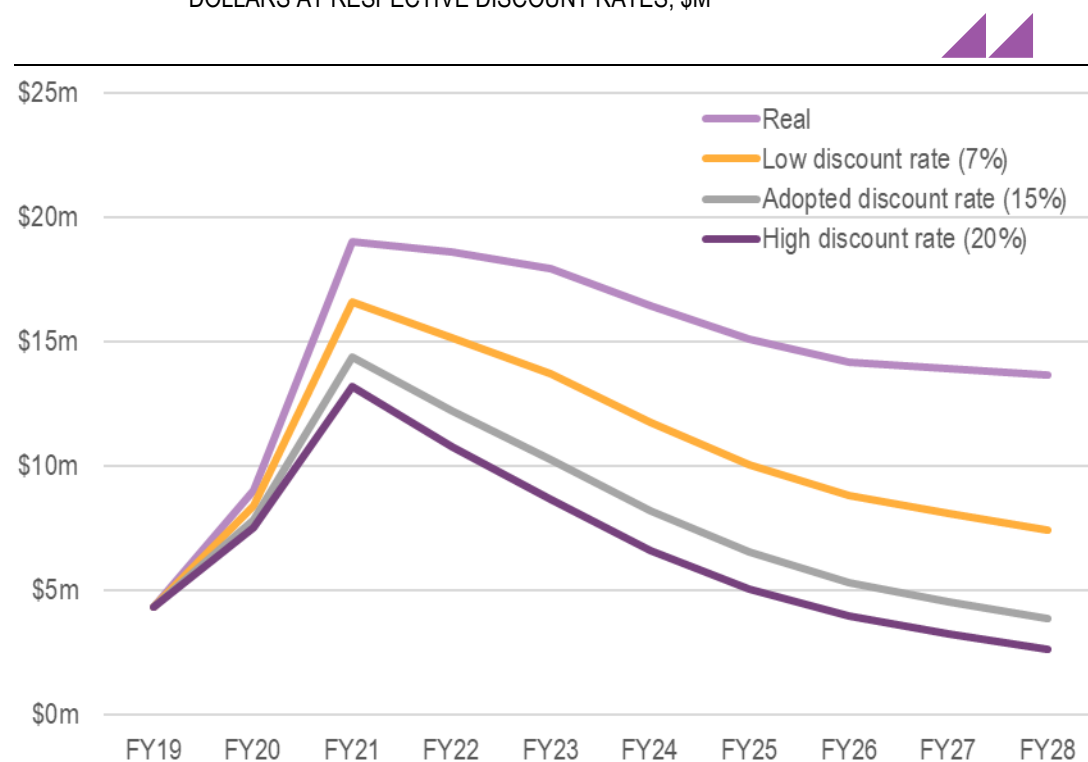
### Discounting future benefit values

Given the benefits related to the quantification of potential future economic benefits, it is important to apply a financial concept known as discounting. The approach is generally used in financial modelling to reflect the uncertainty of future cash flows versus receipt of a dollar today, reflecting the concept of the time value of money.

Selection of an appropriate discount rate (the rate at which future values are reduced) is an important consideration but one which is ultimately subjective. The standard approach to most discount rates is to link it to a cost of capital plus the rate of inflation, such as the ten year bond rate and the Reserve Bank of Australia's target cash rate. For the private sector, a discount rate is generally assessed on the basis of the target rate of return on funds invested, which can vary between industries (for example, energy sector projects can discount future values by 15 to 20 per cent, reflecting a desired rate of return but also the high uncertainty of future cash flows which are dependent on volatile commodity markets). For this study, ACIL Allen has elected for a discount rate of 15 per cent for future economic benefits, to reflect the highly uncertain nature of the task. A higher discount rate will mean future values are worth much less than the same nominal value in today's dollars. However, this is an important means of demonstrating the extent to which benefits are subject to uncertainty.

On a discounted basis, ACIL Allen estimates the quantified benefits of the six research program case studies selected for analysis total \$77.5 million over the ten years 2018-19 to 2027-28, or approximately \$7.7 million per annum. The annual discounted value for the research program case studies versus the undiscounted values and a discounted value at alternative discount rates (seven per cent and 20 per cent) are presented below

**FIGURE 10.2** DIRECT BENEFITS OF RESEARCH PROGRAM CASE STUDIES, DISCOUNTED 2017-18 DOLLARS AT RESPECTIVE DISCOUNT RATES, \$M



SOURCE: ACIL ALLEN CONSULTING

### 10.1.2 Overall research case study benefits summary

The table below summarises the total quantified benefits of each of the research program case studies included in this study, with real and discounted values included. Alongside each of the quantified benefits for each research program case study are a recap of the non-quantified benefits discussed earlier in this Part of the report.

**TABLE 10.1** MRIWA RESEARCH PROGRAM CASE STUDY BENEFITS, SUMMARY

Research Program Case Study	Gross benefit (\$m, 2018-19 dollars)	Discounted benefit (\$m, 2018-19 dollars, 15% discount rate)	Non-quantified benefits of research
Case Study 1: Grade Engineering	15.5	10.6	<ul style="list-style-type: none"> <li>– Application of technology to additional gold mines</li> <li>– Application of technology to additional mineral sectors</li> <li>– Additional positive impact on grades (ie larger impact magnitude)</li> <li>– Bring additional mines into scope</li> </ul>
Case Study 2: mXrap	25.1	14.5	<ul style="list-style-type: none"> <li>– Avoided human cost of seismic events</li> <li>– Additional research projects funded from mXrap profits</li> </ul>
Case Study 3: Wearable Technologies	26.6	14.9	<ul style="list-style-type: none"> <li>– Application to additional mines</li> <li>– Application to additional industries (non-minerals)</li> </ul>
Case Study 4: Gold Exploration	71.5	35.6	<ul style="list-style-type: none"> <li>– Potential for new mineral discoveries and additional mines</li> <li>– Development of new commercial business applying technology</li> </ul>
Case Study 5: Leaching Assessment Technologies	3.5	1.9	<ul style="list-style-type: none"> <li>– Cost savings for miners applying technology</li> <li>– Faster approvals, leading to improved mine economics</li> <li>– Application of technology to additional mineral sectors</li> </ul>
Case Study 6: Coil Tubing Drilling	N/A	N/A	<ul style="list-style-type: none"> <li>– Potential for new mineral discoveries and additional mines</li> </ul>
Total benefits	142.2	77.5	N/A

SOURCE: ACIL ALLEN CONSULTING



# THE ECONOMIC IMPACT OF MRIWA

2022





## 11.1 Introduction and assumptions

ACIL Allen has completed an economic impact assessment using its computable general equilibrium model *Tasman Global* to understand how the forecast direct benefits of the selected elements of the MRIWA's research program may impact on the Western Australian economy. The scenario that has been modelled is presented at the end of Section 10.

In order to facilitate this modelling, ACIL Allen has set the model parameters and adopted a number of overarching assumptions. These are presented below for reference.

- The modelling period is for the ten years 2018-19 (current year) to 2027-28. Results are presented in real 2018-19 dollars, and are undiscounted in the text. Discounted values are presented in a table in Section 11.2.5. Modelling has been produced for Western Australia only as this is the MRIWA's remit.
- The labour market is flexible, which means any additional labour demand created as a result of the impacts of the MRIWA's research program draw additional workers into the labour force (rather than crowding out existing workers and leading to a change in real wages).
- ACIL Allen's return on capital assumptions for large mining companies apply, meaning for relevant case studies only a portion of the income benefit remains in Western Australia (with the remainder heading interstate or overseas to the owners of the capital. All other factors of production (smaller companies, all labour) reside in Western Australia, meaning the income that flows from their product remains in the State.

The remainder of this section discusses the results of the economic impact assessment.

## 11.2 Economic impact assessment results

The economic impact is assessed as the incremental benefits to the Western Australian economy from the baseline over the period from 2018-19 to 2027-28 on the following terms:

- the impact on **real incomes** (a measure of economic welfare or standard of living);
- the impact on **real output** (as measured in terms of Gross State Product),
- the impact on **real consumption** (as measured in terms of household consumption expenditure), and
- the impact on **employment** (as measured on a full time equivalent job basis).

The economic impact of the scenario as detailed in Section 10, was assessed using ACIL Allen's *Tasman Global* CGE model. Further details on *Tasman Global* are presented in Appendix B.

### 11.2.1 Real income

As a statutory body established to stimulate minerals research in Western Australia, the MRIWA's funding activities have a sizable impact on the real income of the State. Real income is a measure of the economic welfare (or standard of living) improvement as a result of the MRIWA's funding activities. The change in real income captures the effect of net foreign income transfers associated with ownership of the capital along with changes in purchasing power of Australian residents.

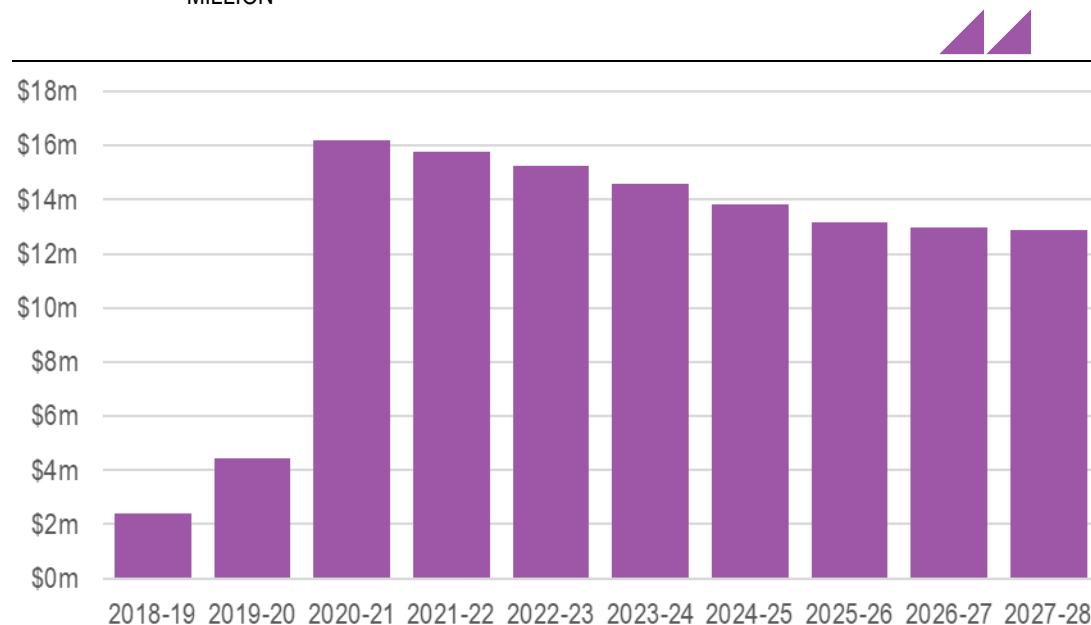
In this assessment, the real income impact of the MRIWA's selected funding cases is largely generated by the increased mining productivity resulting from the new technologies. There are also real income benefits associated with Commonwealth taxation raised from mining revenue in terms of mining royalties.

Overall, the incremental real income impact of the MRIWA's combined research projects is estimated to total \$121.5 million over the 10 year modelling period, at an average of \$12.1 million per annum. The boost to real income in Western Australia is equivalent to 0.05 per cent increase to Western Australia's State Domestic Income (SDI) in 2017-18.

As shown in **Figure 11.1** the real income benefit increases significantly in 2021 and then slowly declines year by year. Between 2021 and 2028, the increase in real income for the State on average is \$14.3 million per annum.

*The incremental real income impact of the MRIWA's funding is estimated at a total of \$121.5m over the 10 year period.*

**FIGURE 11.1** THE MRIWA'S FUNDING ACTIVITIES – REAL INCOME, DEVIATION FROM BASELINE, A\$ MILLION



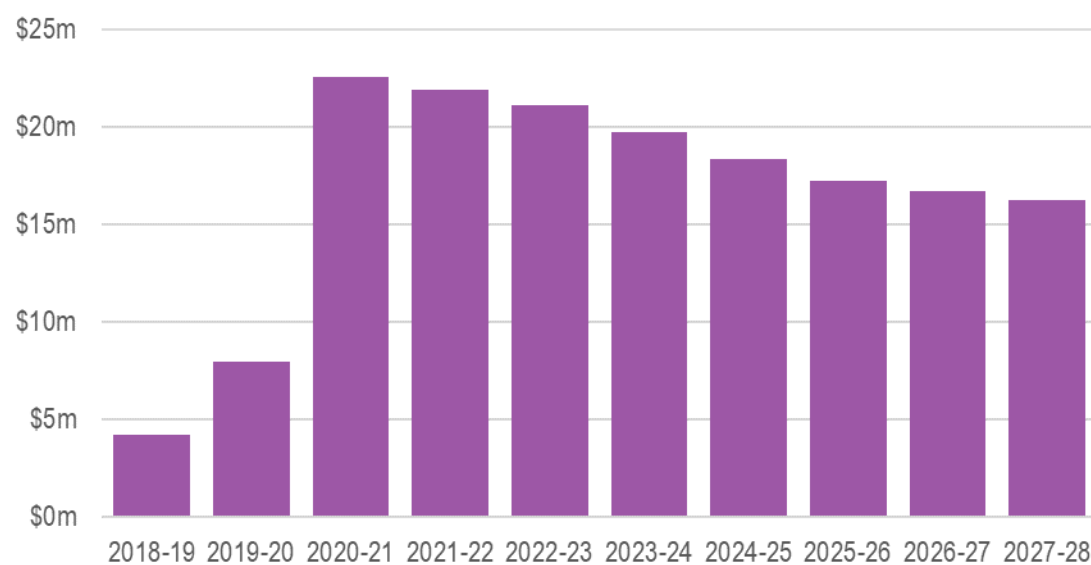
SOURCE: ACIL ALLEN CONSULTING

### 11.2.2 Real output

Real output is a measure of the total domestic production of an economy (region, State or country) in a given year. It differs from real income as it accounts for the effects of the import and/or export of intermediate and final goods and services, and reflects the final value of activity in an economy.

Under the MRIWA's modelled scenario, the incremental real output benefit is estimated to total \$166.0 million at an average of \$16.6 million per annum over the 10 year study period. Similarly to the real income benefit, the real output benefit grows over time in line with the research projects that generate productivity enhancements in the State's mining industry (see **Figure 11.2**). Relative to the size of the Western Australian economy, the average annual change in Western Australia's GSP as a result of this scenario is equivalent to a 0.07 per cent boost to the State's GSP.

*Under this scenario, incremental real output benefit is estimated to total \$166.0 million at an average of \$16.6 million per annum over the 10 year study period.*

**FIGURE 11.2** REAL OUTPUT, DEVIATION FROM BASELINE, A\$ MILLION

SOURCE: ACIL ALLEN CONSULTING

**Real consumption**

Real consumption is a component of real output, which reflects the impact on consumer spending associated with the direct and indirect benefits of the MRIWA research programs. Over the study period, it is estimated that the MRIWA's research programs result in an additional \$42.8 million over ten years, or \$4.3 million per annum.

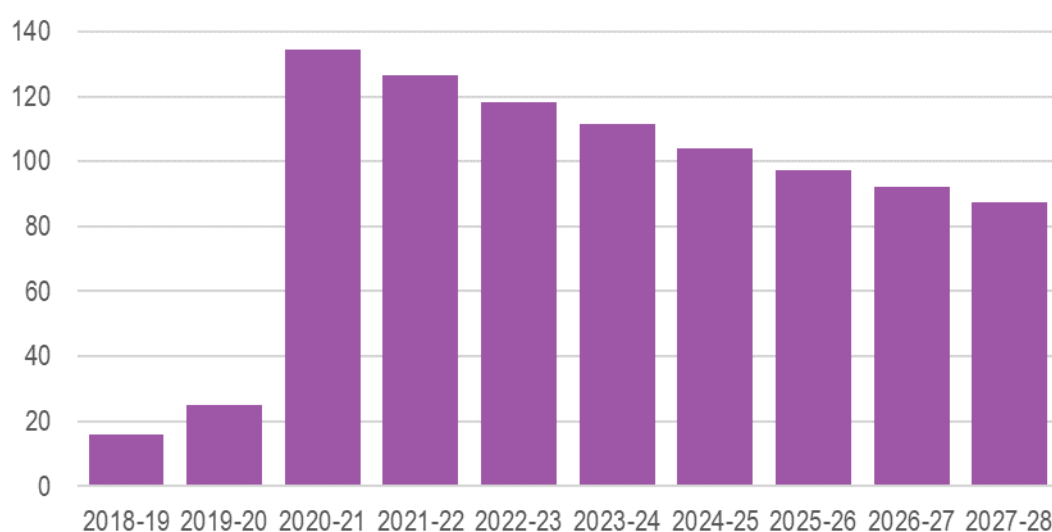
### 11.2.3 Employment

The MRIWA's research funding activities have a sizable impact on Western Australia's labour market, as a number of new Western Australian positions are created as a result of the introduction of several new technologies to the State's mining sector.

*The MRIWA's research project scenario generates an additional 913 FTE jobs for the 10 year study period.*

Over the study period, it is estimated that the MRIWA's research funding activities results in an additional 913 FTE job years over the 10 year assessment period, or an average of 91 FTE job years per annum (see **Figure 11.3**). Growth in employment sharply increases in 2021 by about 134 FTEs. The increase above the baseline then declines year to year to increase by about 87 FTEs in 2028.

**FIGURE 11.3** THE MRIWA'S FUNDING ACTIVITIES: EMPLOYMENT, DEVIATION FROM BASELINE, FTE JOB YEARS



SOURCE: ACIL ALLEN CONSULTING

### 11.2.4 WA Government taxation

As part of these economic impacts, there are also benefits to the State Government's key lines of taxation. ACIL Allen has estimated there are two key benefits: additional payroll tax and additional resources royalties. These impacts are a subset of real income benefits, but have been called out specifically given the frame of reference of this engagement.

ACIL Allen calculates the impact of the six research programs analysed for this assessment will deliver the State an additional \$1.4 million in gold royalties (2017-18 dollars), on account of the impact of the Grade Engineering technology discussed in Case Study 1. In reality the royalty impact is likely to be significantly larger, as assumptions adopted for the assessment are very conservative.

With regards to payroll tax, ACIL Allen has used the outputs of its economic impact assessment in terms of FTE job years created above the baseline, and adopted the 2017-18 WA Average Weekly Full Time Earnings (\$103,823 per annum) as the assumed real wage for these additional job years. Applying Western Australia's payroll tax rate (5.5 per cent) yields an estimated payroll tax impact of \$5.2 million over ten years, or an average of \$0.5 million per annum.

Combined, ACIL Allen's economic impact assessment suggests the six research program case studies prepared for the assessment will deliver the State Government an additional \$6.6 million in taxation revenue over the next ten years (in real 2017-18 dollars), or \$0.7 million per annum.

### 11.2.5 Summary

The following table summarises the economic impacts of the MRIWA's research project funding activities. Overall, the modelling shows there is a clear forecast economic upside associated with the MRIWA's funding activities, and these benefits manifest in both increase consumer spending and increased employment in the local economy.

**TABLE 11.1** THE MRIWA SCENARIO – RESEARCH FUNDING ACTIVITIES

Scenario & benefit/cost	Total	Average	NPV (4%)	NPV (7%)
<b>The MRIWA Research Funding – Western Australia Impacts</b>				
Real income	\$121.5m	\$12.1m	\$100.1m	\$87.6m
Real output	\$166.0m	\$16.6m	\$137.6m	\$120.9m
Real consumption	\$42.8m	\$4.3m	\$34.0m	\$28.9m
Government taxation	\$6.6m	\$0.7m	\$5.6m	\$4.9m
Real employment (FTE)	913	91.3	N/A	N/A

SOURCE: ACIL ALLEN CONSULTING



# 12

## BENEFIT COST ASSESSMENT

### 12.1 Introduction and assumptions

In order to estimate the net social benefit of the MRIWA's research program, ACIL Allen used a Benefit Cost Assessment (BCA) framework. A BCA is a commonly used quantitative framework for logically analysing the social and economic costs and benefits of a particular policy, project or investment. The basis of a BCA is simple: for a given investment proposal or policy reform, a BCA compares the total forecast costs (including opportunity cost) to the community and economy of the investment or policy with the total forecast benefits. This determines whether the benefits outweigh the costs, and by how much.

The output of a BCA is typically expressed as a Benefit Cost Ratio (BCR) where total benefits are divided by total costs. A BCR of greater than one indicates that the net benefits of the policy, project or investment exceed the costs – this suggests economic value in investing in the option. The reverse applies for BCRs below one.

A BCA provides a framework for analysing information in a logical and consistent way by assisting policymakers to determine which investment option is the most economically effective and efficient in achieving the desired outcomes. A BCR of less than one does not automatically preclude the implementation of the policy, project or investment however the business case would typically require strong alternate reasoning such as a clear social policy mandate.

The logical flow of ACIL Allen's BCA framework is presented in this chapter, with results of the analysis included in Section 12.2.3.

### 12.2 Quantitative benefit cost assessments

The quantitative BCA requires definition of both the benefits of the MRIWA and its costs. These are outlined below.

#### 12.2.1 BCA: Quantified benefits

For the purposes of this BCA, ACIL Allen has considered the benefits of the MRIWA accrue as the direct economic benefits calculated for the six research program case studies assessed as part of the economic impact assessment.

However, in the BCA framework it is important to consider the extent to which the benefits generated are realised in Western Australia (a process which occurs in the CGE model for the purposes of the economic impact assessment). ACIL Allen has a standard set of assumptions regarding the attribution of benefits which accrue to large, publicly listed mining companies, which are 12 per cent for profits (reflecting an assumed population share distribution of shareholdings) and 100 per cent for wages

(reflecting that unless otherwise stated all mining sector workers reside in their State of work, whether they are FIFO or residential workers). These ratios apply to

- Case Study 1 (Grade Engineering) as it relates to increased gross value added from affected mines
- Case Study 2 (mXrap) as it relates to mine closure cost savings
- Case Study 3 (Wearable Technologies for Safety) as it relates to iron ore industry cost savings

For all other benefits, it is assumed 100 per cent of the benefit is directly retained in Western Australia on the basis that the nature of the benefit suggests this would be the case. The BCA framework does not consider the indirect economic benefits of an activity and so what happens with the direct benefit (such as the purchase of goods and services which are made outside of Western Australia) does not matter.

One critical underpinning assumption is the attribution of forecast benefits to MRIWA. The attribution of benefits is critical as the purpose of the BCA is to understand the true impact of a particular policy or program – which involves establishing to what extent a given set of benefits would have happened regardless of the respective policy or program intervening.

In this case, ACIL Allen has attributed 100 per cent the relevant benefits to the MRIWA, as during stakeholder consultation each stakeholder identified that either the research program analysed for the case study wouldn't have happened, the research program would not be focussing on Western Australia, or both. However, given this is a somewhat aggressive assumption in the BCA framework ACIL Allen has included BCA ratios for a number of attribution percentages (50 per cent and ten per cent) in addition to the central assumption of 100 per cent attribution.

The consideration of the extent to which benefits are retained in Western Australia has the effect of reducing the direct benefits of the six research program case studies for BCA purposes. Overall, applying the local share ratios presented above to the discounted benefits calculated in Section 10 yields a local direct benefit of \$54.5 million in 2017-18 dollars. This benefit is used as the numerator in both of the quantitative BCA calculations.

### 12.2.2 BCA: Quantified costs

ACIL Allen has included two different assessments of the “costs” associated with the MRIWA's funding of each of these six research programs: the funding of the six research program case studies (inflated to 2017-18 dollars) and the total State Government funds spent to fund MRIWA since 1 February 2014.

The former is included to provide a perspective of the return on investment in the six research programs as a proxy measure for the overall return on investment on individual MRIWA-funded projects. The latter is included to provide a perspective on the extent to which the MRIWA has met its overarching objective of providing a benefit to the State's minerals industry, and whether the State Government's investment in MRIWA is delivering an economic and social return. These are discussed below.

#### Research program costs

The six research program case studies are made up of 20 individual MRIWA/MERIWA projects, 19 of which received funding from MRIWA/MERIWA and one in which MRIWA undertook a project coordination role. These projects are spread from 1998-99 to 2017-18, meaning their investment values need to be adjusted to reflect the value of the investment in today's dollars. ACIL Allen has inflated the values of each individual research project by the Perth CPI over the period between the research project funding decision and the end of the 2017-18 financial year.

In addition, it is important to consider a concept known as opportunity cost when reflecting the true cost of funds – particularly in a government context. Opportunity cost is an economic concept which reflects every decision made results in foregone decisions, which have a cost. In a Government context, WA Treasury advises that all government costing exercises involving the spending of consolidated funds should include an opportunity cost calculation to reflect that if the spending didn't occur the funds could be used for another purpose.



WA Treasury's current advice regarding opportunity cost is for the purposes of analysis and costing of services relevant costs should be increased by four per cent, reflecting the State Government's operating deficit position in the General Government sector and that any savings will be used to reduce the operating deficit and therefore lead to less State Government debt. The four per cent figure is the State Government's approximate rate of interest on borrowings. Opportunity cost should be applied on a compounding basis, reflecting the compound nature of past decisions. This means projects which were funded earlier in the funding period have a much higher opportunity cost rate applied than newer projects.

As a result of the above, ACIL Allen has costed the 20 research projects that form the six research program case studies at \$4.4 million in 2017-18 dollars. This represents a premium of around \$1.9 million on the nominal investments made by MRIWA/MERIWA in the respective year each project was funded.

### **MRIWA cost of services**

The other approach to measuring costs for the purposes of this BCA is to determine the total State Government funding provided to MRIWA since its inception (1 February 2014) which has been spent by MRIWA with the intent of achieving its objectives under the Act. This is different than simply taking total expenditure, or taking the State's total appropriation to MRIWA, as the base, as it reflects the value of *actual* expenditure, given funds which have been transferred but not spent could be withdrawn and returned to the consolidated account. It is also important to deemphasise the private sector component of research project funding, given the BCA is being undertaken from the perspective of the State Government.

To complete this analysis, ACIL Allen received detailed profit and loss statements from MRIWA for the period 1 February 2014 to 30 June 2018, and converted these to a cash flow statement which operated as below:

- The MRIWA initially receives its appropriation from the State Government, which is initially spent on the non-research project activities of MRIWA.
- Any surplus funds are then available for funding research projects. The State Government's share of research project funding in a given year is estimated on the basis of its share of total funding amounts in projects approved in the year.
- Any surplus funds are then held over for the year, and are available for future funding of the MRIWA.
- This process repeats from 1 February 2013 to 30 June 2018.

In addition, MRIWA receives its office accommodation free of charge, which is added to the annual State Government expenditure value. Like the research program costs, expenditure is then adjusted to real 2017-18 dollars, and opportunity cost is added.

As a result of the above, ACIL Allen calculates MRIWA has cost the State Government \$13.7 million between 1 February 2014 and 30 June 2018 in real 2017-18 dollars. This compares to a total State Government appropriation and services received free of charge of \$22.9 million – the difference reflecting funds which have been transmitted to MRIWA from the Consolidated Account but which have not been spent.

In reality, a portion of these funds are sitting in escrow awaiting disbursement for projects which have been approved but where milestones (such as research deliverables) have not yet been met. These funds are subject to bonafide contracts and so could not be repurposed in the event surplus funds were to be returned to the Consolidated Account. It is therefore important to consider these as part of the "spent" funds for the purpose of the BCA.

ACIL Allen's calculations suggest the MRIWA is currently holding a \$7.7 million worth of funds appropriated to it. MRIWA's 2017-18 annual report shows of its total current financial assets that 47.2 per cent are in the restricted cash or cash equivalents category.<sup>16</sup> Applying this ratio yields an

<sup>16</sup> A proportion of this presently unrestricted cash has been committed to projects but is yet to be formally contracted as part of a research project. Therefore under this frame of reference it represents money which is "unspent" for the purposes of calculating the cost of MRIWA to the State.

additional \$3.7 million of State Government appropriation that has already been spent but is yet to be disbursed. Adding opportunity cost takes this value to \$3.8 million.

The total cost of MRIWA to the State since its inception is therefore calculated as \$17.4 million in real 2017-18 dollars.

### 12.2.3 BCA: Benefit cost assessment of MRIWA

Using the information presented above, ACIL Allen can calculate a number of quantitative net benefits (benefits less costs) and benefit cost ratios (BCRs) for the MRIWA. These are presented below.

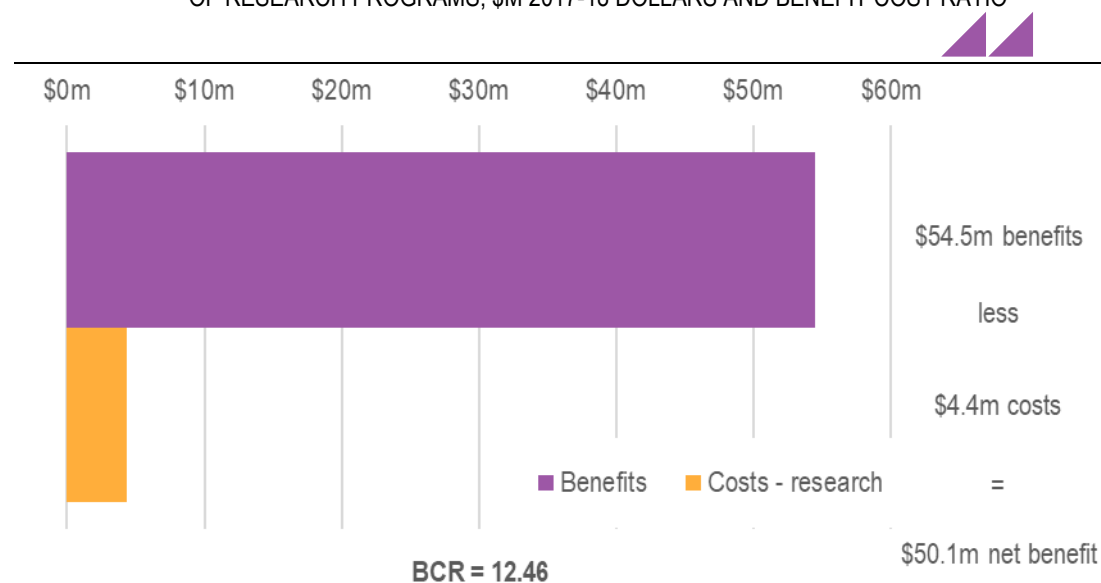
#### MRIWA Research Program Benefits vs Research Program Costs

ACIL Allen estimates MRIWA's six research programs are forecast to deliver at least a net benefit of \$50.1 million, being that the research program is forecast to deliver benefits of \$54.5 million versus a research funding cost to the State of \$4.4 million. This BCA is summarised in the figure below (Figure 12.1).

Under the assumptions adopted above, the BCR of the MRIWA's research program as described above is 12.46, implying that for these research programs every dollar of State Government funding is forecast to produce \$12.46 of benefits. This is a significant result, even under conservative assumptions such as a compounding of the opportunity cost rate as a means of inflating costs and adopting an aggressive discount rate of 15 per cent.

The table at the end of this section presents a number of BCRs under different assumption sets for rates of attribution, benefit discount rate and opportunity cost of State funding.

**FIGURE 12.1** MRIWA BENEFIT COST ASSESSMENT, RESEARCH PROGRAM BENEFITS VS FUNDING OF RESEARCH PROGRAMS, \$M 2017-18 DOLLARS AND BENEFIT COST RATIO

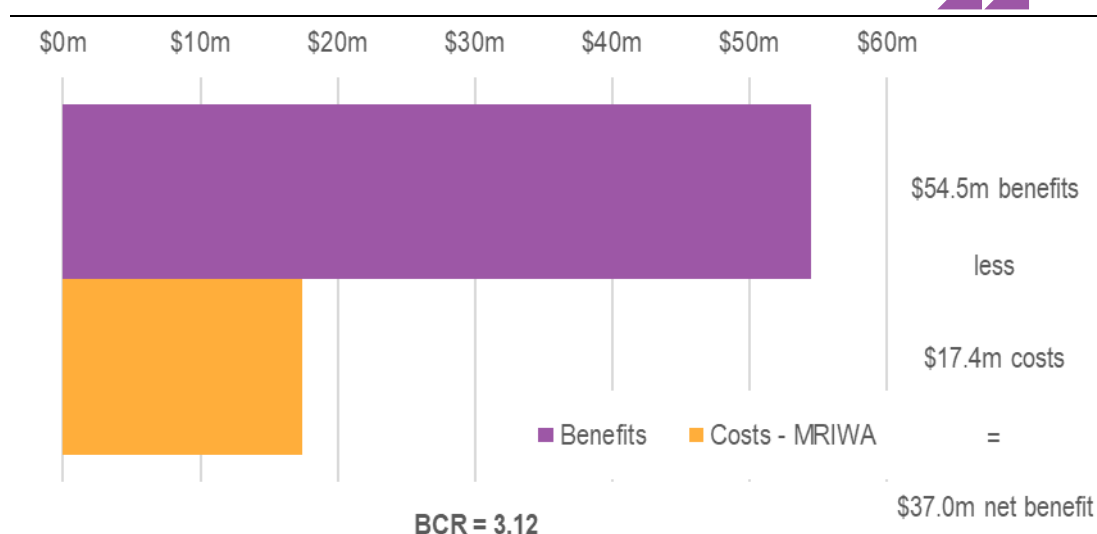


SOURCE: ACIL ALLEN CONSULTING (VALUES ROUNDED TO THE NEAREST \$100,000)

#### MRIWA Research Program Benefits vs MRIWA Cost of Services

ACIL Allen estimates MRIWA's cost of services are forecast to deliver at least a net benefit of \$37.0 million, being that the research program is forecast to deliver benefits of \$54.5 million versus the cost to the State of the MRIWA's operations since its inception on 1 February 2014 of \$17.4 million. This BCA is summarised in the figure below (Figure 12.2).

**FIGURE 12.2** MRIWA BENEFIT COST ASSESSMENT, RESEARCH PROGRAM BENEFITS VS MRIWA COST OF SERVICES, \$M 2017-18 DOLLARS AND BENEFIT COST RATIO



SOURCE: ACIL ALLEN CONSULTING (VALUES ROUNDED TO THE NEAREST \$100,000)

Under the assumptions adopted above, the BCR of the MRIWA operations since its inception is 3.12, implying that for these research programs every dollar of State Government funding is forecast to produce at least \$3.12 of benefits. ACIL Allen has calculated this BCR as a means of demonstrating the role the MRIWA has played in fostering research projects that began under its precursor body. These are ultimately expected to result in the translation of significant benefits to the State's minerals industry well in excess of the MRIWA's cost of services in its current form.

The BCR is also significant insofar as:

- MRIWA has funded more than 350 individual pieces of research over its history (MRIWA and MERIWA), including 50 projects since MRIWA's inception with a total project value of \$19.2 million (nominal terms). The BCR considers the potential benefits of just 20 of those pieces of research, with a value of \$2.4 million.
- The calculation of benefits has been completed using a conservative methodology (which doesn't consider many of the highest value but most difficult to predict benefits such as spurring the development of a new mine) and with a conservative discount rate (15 per cent).
- The calculation of benefits does not include the first round direct economic benefits of the MRIWA's expenditure, such as the consumption impact of wages and salaries paid to MRIWA staff or the employment impacts of research project funding (ie without funding some researchers may not be employed)
- The calculation of benefits does not include many of the intangible benefits of the MRIWA's operations, such as knowledge transfer, research linkages, and reputational benefits to the State, which all stakeholders indicated was an important part of the MRIWA's value to Western Australia
- The MRIWA's cost of services also includes \$3.7 million of funds currently held in escrow, which deliver no tangible benefit but add to the MRIWA's cost of services.

Given this, even though a BCR of 3.12 demonstrates a substantial forecast return on investment for the State, it is almost certainly underselling the tangible and intangible benefits of the MRIWA to the State of Western Australia. These are discussed in Section 12.3.

The table at the end of this section presents a number of BCRs under different assumption sets for rates of attribution, benefit discount rate and opportunity cost of State funding.

**Benefit cost ratios: Sensitivity testing**

Below are a number of BCR ratios prepared using variations on the critical assumptions regarding discount rate for future benefits, opportunity cost for past expenditures, and rate of benefit attribution. The first table (**Table 12.1**) demonstrates BCRs for the assessment that uses the research program funding cost only as the base for the assessment, while the second (**Table 12.2**).

The figures in the table below are presented as a means of sensitivity testing the outputs of each BCA only. As such, ACIL Allen's actual BCR for each of the cost bases is bolded in the table.

**TABLE 12.1** BCR SENSITIVITY TESTING, MRIWA RESEARCH PROGRAM COST BASE

Attribution rate: 100%				
		Opportunity cost		
		High (6%)	Base (4%)	Low (2%)
Future benefit discounting	High (20%)	8.49	10.53	12.91
	Base (15%)	10.05	<b>12.46</b>	15.29
	Low (7%)	13.68	16.97	20.81
Attribution rate: 50%				
		Opportunity cost		
		High (6%)	Base (4%)	Low (2%)
Future benefit discounting	High (20%)	4.24	5.26	6.46
	Base (15%)	5.03	6.23	7.64
	Low (7%)	6.84	8.48	10.41
Attribution rate: 10%				
		Opportunity cost		
		High (6%)	Base (4%)	Low (2%)
Future benefit discounting	High (20%)	0.85	1.05	1.29
	Base (15%)	1.01	1.25	1.53
	Low (7%)	1.37	1.70	2.08

SOURCE: ACIL ALLEN CONSULTING

**TABLE 12.2** BCR SENSITIVITY TESTING, MRIWA COST OF SERVICES COST BASE

Attribution rate: 100%				
		Opportunity cost		
		High (6%)	Base (4%)	Low (2%)
Future benefit discounting	High (20%)	2.52	2.64	2.75
	Base (15%)	2.99	<b>3.12</b>	3.26
	Low (7%)	4.07	4.25	4.44
Attribution rate: 50%				
		Opportunity cost		
		High (6%)	Base (4%)	Low (2%)
Future benefit discounting	High (20%)	1.26	1.32	1.38
	Base (15%)	1.63	1.56	1.63
	Low (7%)	2.03	2.12	2.22

Attribution rate: 10%				
		Opportunity cost		
		High (6%)	Base (4%)	Low (2%)
Future benefit discounting	High (20%)	0.25	0.26	0.28
	Base (15%)	0.30	0.31	0.33
	Low (7%)	0.41	0.42	0.44

SOURCE: ACIL ALLEN CONSULTING

Overall, the sensitivity testing shows the BCR results are most sensitive to the assumption regarding attribution; a low attribution rate is enough to see a negative BCR (less than one) across all other assumption sets in the study that consider the MRIWA's cost of services. However, this should be balanced against the finding that even under a very low attribution scenario that the six research case studies are able to deliver a positive BCR (in all except the most aggressive assumption set).

This suggests when MRIWA is able to procure a project which leads to a demonstrable outcome in the local economy that it is able to achieve a positive return on the funds invested by the State Government. However, it also suggests the MRIWA must remain vigilant in its assessment of projects as a handful of large ones which don't have a good outcome could impact on the firm.

### 12.3 Qualitative benefits and overall assessment

In addition to the quantified benefits, there are a number of other benefits delivered by the MRIWA which are more intangible in nature. These are benefits which ACIL Allen has uncovered during its program of stakeholder consultation, which is considered important to understanding the overall benefit of MRIWA to the State of Western Australia. These qualitative benefits include:

- The MRIWA's role in creating linkages between researchers and industry members, which would have otherwise not formed. These linkages can result in knowledge transfer or the development of research programs which are entirely separate from MRIWA but still deliver upon its priorities. These kinds of relationships have not been quantified as part of this benefit cost assessment.
- One of the MRIWA's Research Priority Plan areas is Find More Resources. ACIL Allen made a conceptual decision to exclude these from its scope of quantification, as the development of a new mine requires more than simply finding the resource. Notwithstanding, if technologies supported by MRIWA resulted in the development of just one mine in Western Australia the State Government's investment in MRIWA will have a positive benefit cost ratio.
- The MRIWA helps enhance Western Australia's reputation as a positive place for the minerals industry, by signalling the State's interest in and desire to foster the minerals industries. This may attract global multi-national corporations or smaller companies to set up a base of operations in the town.

These qualitative benefits are essentially additive to the research case studies analysed in this section.



# 13

## SUMMARY AND FINDINGS

Overall, it is clear from ACIL Allen's analysis that the MRIWA delivered significant value to the State of Western Australia. Each of the individual direct benefits of the six research program case studies, the overall economic impact assessment, or the benefit cost assessment concur that the MRIWA affords the Western Australian Government a number of benefits in excess of the MRIWA to Western Australians.

ACIL Allen's conservative approach to case study quantification has still yielded a significantly positive result, with direct benefits to Western Australia exceeding the MRIWA's annual budget for the past 4.5 years at over 3.5 to one. When compared just to the MRIWA's funding of individual research programs, the benefits are enormous: 12.90 to one, without any consideration of the "Find More Resources" aspect of the MRIWA's research priority plan.

With regards to the economic impact assessment, ACIL Allen finds the MRIWA's research program delivers \$121.5 million in real income benefits to Western Australian businesses, people and government agencies. The MRIWA's research program also results in the creation of 913 job years over the ten year study period, and conservatively delivers an additional \$6.6 million in State Government taxes.

Considering the above, ACIL Allen's conclusion is the MRIWA delivers significant value for money for the Western Australian Government, and produces real and tangible benefits to the Western Australian minerals sector that would otherwise not be realised.

# APPENDICES





ACIL Allen Consulting is Australia's largest independent economics, public policy and strategy advisory firm. As a firm, we specialise in economic analysis, and in understanding how policy decisions can translate into socio-economic outcomes. ACIL Allen has significant resources upon which it can draw. We employ around 80 consultants located in Canberra, Sydney, Brisbane, Melbourne, Adelaide and Perth.

The firm has built a reputation for quality research, credible analysis, and innovative advice on economic, policy and strategic matters over a period of more than twenty years. ACIL Allen operates across a select range of industries including energy, mineable resources, water and other infrastructure, education, tourism, health and human services policy and provides specialist advice to companies, governments, regulators and industry associations. ACIL Allen has been at the forefront of analysis of changes and policy issues in these sectors. We have helped governments to develop a number of policy mechanisms applied in response to these changes and policy issues. We have also helped many private corporations to develop responsive business strategies in this dynamic environment.

Our analytical and modelling skills enable us to provide robust quantitative estimates of the impacts of market and regulatory risk. We often use risk-based decision tools such as real options frameworks to advise clients on risk management strategies and opportunities. In part, our experience in these roles relates to major infrastructure assets, supporting feasibility assessments, equity raisings, sale and acquisition processes and funding of infrastructure assets, including natural gas and electricity transmission and distribution systems, power stations, roads, railways, airports and ports.

Our consultants are drawn from a wide variety of disciplines including economics, finance, statistics, geology, physics, environmental science, engineering and mathematics. We also offer a diverse range of professional backgrounds in state and federal government, academia and business.

Our suite of services include:

- developing or evaluating programs and projects for a range of clients;
- stakeholder consultation, which includes undertaking surveys, interviews and focus groups;
- policy analysis and formulation for government agencies and private sector organisations;
- strategy development for government, private sector organisations and sectors;
- economic impact analysis of specific markets and sectors;
- economic and financial analyses for companies and government agencies, including benefit-cost analysis;
- feasibility studies and project evaluation;
- regional/spatial modelling and mapping;
- projections of demand with respect to particular assets or supply systems;



- risk and investment analysis; and
- analysis of regulatory processes governing industries, assets and other infrastructure including the establishment of third-party access arrangements and reference tariffs.

Further information can be found on ACIL Allen's website at [www.acilallen.com.au](http://www.acilallen.com.au)



ACIL Allen's computable general equilibrium model *Tasman Global* is a powerful tool for undertaking economic impact analysis at the regional, state, national and global level.

There are various types of economic models and modelling techniques. Many of these are based on partial equilibrium analysis that usually considers a single market. However, in economic analysis, linkages between markets and how these linkages develop and change over time can be critical. *Tasman Global* has been developed to meet this need.

*Tasman Global* is a large-scale computable general equilibrium model which is designed to account for all sectors within an economy and all economies across the world. ACIL Allen uses this modelling platform to undertake industry, project, scenario and policy analyses. The model is able to analyse issues at the industry, global, national, state and regional levels and to determine the impacts of various economic changes on production, consumption and trade at the macroeconomic and industry levels.

### A Dynamic Model

*Tasman Global* is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before a policy change and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues where both the timing of and the adjustment path that economies follow are relevant in the analysis.

### The Database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database we will use for this project is derived from the Global Trade Analysis Project (GTAP) database (version 8.1). This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities.

The GTAP model was constructed at the Centre for Global Trade Analysis at Purdue University in the United States. It is the most up-to-date, detailed database of its type in the world.

*Tasman Global* builds on the GTAP model's equation structure and database by adding the following important features:

- dynamics (including detailed population and labour market dynamics)
- detailed technology representation within key industries (such as electricity generation and iron and steel production)
- disaggregation of a range of major commodities including iron ore, bauxite, alumina, primary aluminium, brown coal, black coal and LNG

- the ability to repatriate labour and capital income
- a detailed emissions accounting abatement framework
- explicit representation of the states and territories of Australia
- the capacity to explicitly represent multiple regions within states and territories of Australia

Nominally the *Tasman Global* database divides the world economy into 141 regions (133 international regions plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Allen regularly models Australian projects or policies at the regional level.

The *Tasman Global* database also contains a wealth of sectoral detail currently identifying up to 70 industries (Table 1). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands. Industry demands, so-called intermediate usage, are the demands from each industry for inputs.

For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input. Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in *Tasman Global*, the electricity, transport and iron and steel sectors are modelled using a ‘technology bundle’ approach. With this approach, different known production methods are used to generate a homogeneous output for the ‘technology bundle’ industry. For example, electricity can be generated using brown coal, black coal, petroleum, base load gas, peak load gas, nuclear, hydro, geothermal, biomass, wind, solar or other renewable based technologies – each of which have their own cost structure.

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.

### Factors of Production

Capital, land, labour and natural resources are the four primary factors of production. The capital stock in each region (country or group of countries) accumulates through investment (less depreciation) in each period. Land is used only in agriculture industries and is fixed in each region. *Tasman Global* explicitly models natural resource inputs as a sector specific factor of production in resource based sectors (coal mining, oil and gas extraction, other mining, forestry and fishing).

### Population Growth and Labour Supply

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for the 112 international regions and for the 8 states and territories of Australia represented in the *Tasman Global* database is projected using ACIL Allen’s in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projection period.

For each of the 120 regions in *Tasman Global*, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance, etc.). Participation rates are a function of life expectancy as well as expected changes in higher education rates, fertility rates and changes in the workforce as a share of the total population.

Labour supply is derived from the combination of the projected regional population by age by gender and the projected regional participation rates by age by gender. Over the projection period labour supply in most developed economies is projected to grow slower than total population as a result of ageing population effects.

For the Australian states and territories, the projected aggregate labour supply from ACIL Allen's demographics module is used as the base level potential workforce for the detailed Australian labour market module, which is described in the next section.

TABLE 1 – SECTORS IN THE *TASMAN GLOBAL DATABASE*

Sector	Sector
1 Paddy rice	36 Paper products, publishing
2 Wheat	37 Diesel (incl. nonconventional diesel)
3 Cereal grains nec	38 Other petroleum, coal products
4 Vegetables, fruit, nuts	39 Chemical, rubber, plastic products
5 Oil seeds	40 Iron ore
6 Sugar cane, sugar beef	41 Bauxite
7 Plant- based fibres	42 Mineral products nec
8 Crops nec	43 Ferrous metals
9 Bovine cattle, sheep, goats, horses	44 Alumina
10 Animal products nec	45 Primary aluminium
11 Raw milk	46 Metals nec
12 Wool, silk worm cocoons	47 Metal products
13 Forestry	48 Motor vehicle and parts
14 Fishing	49 Transport equipment nec
15 Brown coal	50 Electronic equipment
16 Black coal	51 Machinery and equipment nec
17 Oil	52 Manufactures nec
18 Liquefied natural gas (LNG)	53 Electricity generation
19 Other natural gas	54 Electricity transmission and distribution
20 Minerals nec	55 Gas manufacture, distribution
21 Bovine meat products	56 Water
22 Meat products nec	57 Construction
23 Vegetables oils and fats	58 Trade
24 Dairy products	59 Road transport
25 Processed rice	60 Rail and pipeline transport
26 Sugar	61 Water transport
27 Food products nec	62 Air transport
28 Wine	63 Transport nec
29 Beer	64 Communication
30 Spirits and RTDs	65 Financial services nec
31 Other beverages and tobacco products	66 Insurance
32 Textiles	67 Business services nec
33 Wearing apparel	68 Recreational and other services
34 Leather products	69 Public Administration, Defence, Education, Health
35 Wood products	70 Dwellings

## The Australian Labour Market

*Tasman Global* has a detailed representation of the Australian labour market which has been designed to capture:

- different occupations
- changes to participation rates (or average hours worked) due to changes in real wages
- changes to unemployment rates due to changes in labour demand
- limited substitution between occupations by the firms demanding labour and by the individuals supplying labour
- limited labour mobility between states and regions within each state.

*Tasman Global* recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms who hire labour are provided with some limited scope to change between these 97 labour types as the relative real wage between them changes. Similarly, the individuals supplying labour have a limited ability to change occupations in response to the changing relative real wage between occupations. Finally, as the real wage for a given occupation rises in one state relative to other states, workers are given some ability to respond by shifting their location. The model produces results at the 97 3-digit ANZSCO (Australian New Zealand Standard Classification of Occupations) level.

The labour market structure of *Tasman Global* is thus designed to capture the reality of labour markets in Australia, where supply and demand at the occupational level do adjust, but within limits.

Labour supply in *Tasman Global* is presented as a three stage process:

- labour makes itself available to the workforce based on movements in the real wage and the unemployment rate;
- labour chooses between occupations in a state based on relative real wages within the state; and
- labour of a given occupation chooses in which state to locate based on movements in the relative real wage for that occupation between states.

By default, *Tasman Global*, like all CGE models, assumes that markets clear. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model).

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