Established and supported under the Australian Government's Cooperative Research Centres Program

Centre for Sustainable Resource Processing

Cooperative Research Centre for Sustainable Resource Processing
Annual Report 09/10

Vision

The sustainable processing of minerals and metals – contributing to the global material needs of society with a fraction of current ecological impacts.

Mission

To progressively eliminate waste and emissions in the minerals cycle, while enhancing business performance and meeting community expectations.

Participants

Alcoa, Australian Nuclear Science and Technology Organisation (ANSTO), BHP Billiton, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Curtin University of Technology, Newmont, Rio Tinto, University of Queensland, Xstrata, Anglo Platinum, BlueScope Steel, OneSteel, Orica, Rocla, Department of Environment Water Heritage and the Arts, GHD, Hatch, Kwinana Industries Council, Minerals Council of Australia, Murdoch University, University of Newcastle, URS

Contents

Executive Summary

The CRC for Sustainable Resource Processing has now completed its seven year term. The investment by government and industry has resulted in many new technologies which will improve the minerals industry's contribution to a more sustainable society.

CSRP participants are justifiable proud of the outputs from CSRP and enthusiastic about the prospects for significant sustainability benefits which will result from their application.

The success of CSRP can be measured by the statistics, with more than 90 percent of our original objectives met over the seven years and meeting all financial targets, reporting targets and governance requirements. But the true success of CSRP goes much deeper than that. **Through a series of national and international collaborations, CSRP has developed and demonstrated many new technologies to increase energy and water efficiency and to decrease waste production in the minerals cycle.** Some of these are already nearing commercial implementation whilst others will be developed and implemented by CSRP participants and non-participants over the next few years. These outcomes after just seven years are significant and particularly pleasing if one recalls that, according to a CRC Program-commissioned report, returns from CRCs are achieved only after some 11 years on average and that for the minerals industry (where very large financial investments are required), change can often take even longer to implement.

Our most enduring legacy will no doubt be the affect that we have had through the thousands of people that CSRP has touched during its seven years. More than 200 researchers, 60 postgraduate students, 20 research organisations and 50 companies have been involved in CSRP research projects. More than 2000 members of the public have attended CSRP run professional development courses. We have collaborated with more than a dozen international groups in Asia, South Africa, Europe, South America and North America. We have worked with over 20 government organisations in Australia to promote and demonstrate the outputs from CSRP. **Every individual who has worked with CSRP has developed a more holistic understanding of issues of sustainable development.** And each one of them has the opportunity to influence many more people and their views on sustainability issues in their professional and personal lives.

The task for CSRP in its seventh and final year of operation has been to consolidate its outputs into technology packages for uptake (utilisation and commercialisation) and to further develop a number of exciting areas – in particular, sustainability management techniques and the utilisation of mineral processing waste by-products.

With the winding-up of CSRP, I would like to take this opportunity to thank all of those who contributed to and took an interest in our work. It has been a great pleasure to work with so many talented and enthusiastic people. I take special pride in the fact that we enabled several collaborations that would not normally occur and the synergies created from those collaborations have delivered some amazing results.

There are now many opportunities for individual organisations and groups to take up the outputs of CSRP's efforts and the further challenges identified to make further worthwhile contributions to what we all ultimately require – **a truly sustainable society for the future**. I look forward to seeing the results unfold over time.

Stevan Green
Chief Executive Officer

Malcolm Macpherson
Chairman

National research priorities

CSRP's research program covered two of Australia's National Research Priorities. The main focus has been based in the "Environmentally Sustainable Australia" priority. Leading-edge research has also crossed into the "Frontier Technologies for Building and Transforming Australian Industries" priority, with many of the technologies and tools developed being used in industries other than the mineral processing industry. The table below reflects how CSRP has contributed to Australia's National Research Priorities.

NATIONAL RESEARCH PRIORITIES	CRC RESEARCH (%)
An Environmentally Sustainable Australia – Transforming the way we use our land, water, mineral and energy resources through a better understanding of environmental systems and using new technologies	
Water – a critical resource	5
Transforming existing industries	30
Overcoming soil loss, salinity and acidity	5
Reducing and capturing emissions in transport and energy generation	30
Sustainable use of Australia's biodiversity	10
Frontier Technologies for Building and Transforming Australian Industries – Stimulating the growth of world-class Australian industries using innovative technologies developed from cutting-edge research	
Breakthrough science	10
Advanced materials	10

Wind-up

The CRC for Sustainable Resource Processing (CSRP) was established in 2003 under a Commonwealth Agreement administered by the Department of Innovation, Industry, Science and Research. The grant period under the Commonwealth Agreement ended on 30 June 2010.

The substantive achievements of CSRP's research and development over the past seven years are summarised in our legacy "highlights" document published in late 2010.

The winding-up of CSRP was a comprehensive effort that made arrangements for finalising the following areas of activity:

- Research
- Commercialisation, utilisation and intellectual property management
- Education, training and students
- Financial management and budget
- Governance and management
- Residual activities after the grant period
- Final annual report requirements

The Department of Innovation approved our wind-up plan on 25 May 2010.

The wind-up team and Audit Committee supervised the development, implementation and monitoring of the wind-up activities through regular meetings and reporting. The participants put the wind-up plan into effect through execution of the wind-up deed, which detailed all activities including intellectual property assignment and commercialisation. Under the wind-up deed, all intellectual property has been assigned to CSRP participants to further develop and exploit the outputs from CSRP's research.

The majority of research activities on CSRP projects were completed by 30 June 2010, with final project reports delivered by 31 August 2010. Arrangements have been made to ensure that any continuing postgraduate students have the appropriate resources and supervision to allow them to complete their research training.

The wind-up period concluded on 31 October, with Curtin University appointed as the wind-up agent for any wind-up activities after that date (e.g. archiving, website maintenance, etc). To follow-up on any of CSRP's research outcomes and achievements, please contact the respective research or industry participants.

Research Activities and Achievements

During our final year of operation, CSRP's research program continued to develop fundamental understandings of the various mechanisms involved in sustainable resource processing and also increased activities associated with development and demonstration of tangible outcomes for the industry.

In the past seven years, CSRP's research has made important breakthroughs in reducing greenhouse gas emissions, improving operating efficiencies, reusing wastes as valuable by-products, technology transfer and people skilling. These achievements, supported by the development of a sustainability framework for mineral processing, have laid the foundation for step changes in the minerals industry.

Major achievements and activities from CSRP for 2009/10 are listed below. The following sections provide details and highlights from each program, and include summaries of each of the individual projects.*

Highlights from the Year

Delivering sustainable development:

- Completion and publication of the SUSOP® Foundation Manual – This will be the basis for further development of the SUSOP® concept, to allow industry to incorporate sustainable development principles into the design and operation of their industrial processing plants.
- Two 'live' SUSOP® case studies undertaken for BHP Billiton Aluminium and BHP Billiton Stainless Steel Materials Group for identifying and prioritising sustainable development opportunities. Positive outcomes are arising from utilising sustainability measures to enhance profitability while addressing environmental and social issues. A first test case study demonstrated the gap between company policy and application in operations.

World firsts in modelling capabilities:

- A world first slurry model has coupled fluid flow (SPH) and solids flow (DEM) and has been used to analyse the slurry flow in grinding mills.
- Fine ore particles have been included in the simulation of a laboratory-size ball mill to explore what these do to the flow and what breakage environment they experience – a computationally extremely challenging and the first study of its type.

Improved understanding of comminution circuit components:

- Enhanced modelling capabilities that can be used to predict how well banana (multi-slope) screens separate the ore from fines, with a view to optimising separation efficiency, capacity and wear.
- There is a limit to the number of times that an ore can be crushed efficiently by High Pressure Grinding Rolls (HPGRs) used in series. Following a reasonably large size reduction ratio on the first and second passes, a drop in grinding efficiency is experienced on the third pass – indicating a limit of two HPGR passes for efficient grinding of hard ores.

Beneficial uses for bauxite residues:

- A nutrient stripping filter constructed from bauxite residue and gypsum has been effective in controlling the pH and removing phosphorus and other contaminants from water flowing into the wetland.
- A public review on the use of bauxite residue as a soil amendment has shown strong public support for the by-product.
- Encouraging construction trials and environmental results for the use of ReSand® from bauxite residue.

Demonstrating geopolymer concretes:

- A second geopolymer concrete path was laid at Curtin University, using a blend of two Australian fly ashes.
- A geopolymer composition was developed that proved to be suitable for spray coating in terms of flow and spray ability – making it suitable for fire-proofing applications.
- A sustainability metrics calculator was developed that compares selected sustainable development metrics for geopolymer concretes with Portland cement concretes.

Early removal of minor elements:

- Processes for the early removal of arsenic from copper ores show promise in reducing ecological impacts.

* All work on projects in the CO2 Breakthrough in Metal Production Program was completed prior to 2009/10, and as such this program is not reported on this year.

Sustainable Development Program

Program Leader: Prof David Brereton (University of Queensland)

This program incorporated sustainable development assessment tools, analysis and methodologies; regional synergies; water management; and various case studies (both within CSRP and external, including existing operations and proposed industrial developments). The program delivered an innovative approach for the sustainable design of mineral processing operations that can be easily applied by practising design engineers and provides a link between practices at plant level and over-arching sustainability goals. The research outcomes will assist operations to link performance imperatives to sustainability objectives by facilitating a structured, methodical process to identify and implement ways to use less water and energy, generate lower greenhouse gas emissions and minimise waste volume and toxicity.

Program Highlights

- Completion and publication of the SUSOP® Foundation Manual.
- Two 'live' case studies undertaken for BHP Billiton for identifying and prioritising sustainable development opportunities.
- Promising scenarios identified for evaporative water supply/treatment systems and effluent synergies in the Kwinana Industrial Area.
- Extensive database developed for synergy opportunities in the Kwinana Industrial Area and a corresponding list most likely to be supported by industry.
- Great potential for new synergies emerging from the proposed East Rockingham Waste Water Treatment Plant in the Rockingham Industry Zone – and implementation plans developed to assist with the further development of the synergy opportunities identified and the odour footprint assessment.
- Complete draft of the minerals sustainability textbook written – with anticipated release in June 2011.
- Case study findings illustrated how a Newmont gold mine can become more water efficient by running simulations, including alternative options in site water distribution given site needs and efficient layout of water inputs and stores.
- PhD student Robbie Cocks was awarded "best paper" during the proceedings of the Goldfields Environmental Management Group conference.

Sustainable Development Program Extension (101)

This project delivered a toolkit of methods to facilitate the identification and implementation of ways to use less water and energy, generate lower greenhouse gas emissions and minimise waste volume and toxicity. This allows operations to link operating plant performance requirements to sustainability objectives. A related but different activity was the development of a menu driven options approach to address important sustainability issues, such as climate change, across industrial regions. Through the development and deployment of the SUStainable OPerations (SUSOP®) concept, industry will be able to incorporate sustainable development principles into the design and operation of their industrial processing plants.

Development of the SUSOP® concept in 2009/10 has resulted in the undertaking of two 'live' SUSOP® case studies for BHP Billiton, both of which are separate to this project. The first case study was competed at the end of March 2010 and the second case study was completed by the end of August. The outcomes from these 'live' case studies have enhanced the development of SUSOP®, particularly in the concept and pre-feasibility stages of a new engineering study.

The team undertook a total of four SUSOP® workshops, for both BHP Billiton Aluminium and BHP Billiton Stainless Steel Materials Group, for identifying and prioritising sustainable development opportunities for their respective 'live' case studies. For both case studies, the SUSOP® process identified sustainability opportunities and risks or constraints that would not normally be identified through the normal project management process.

The third and fourth workshops were held with the CSRP Sustainable Development project group to further progress the development of the SUSOP® Foundation manual. The manual was completed and published in October 2010.

SUSOP® papers have been published in Minerals Engineering journal, in the proceedings of the Society for Sustainability and Environmental Engineering conference held in Melbourne in September 2009, and also the Sustainable Mining conference held in Kalgoorlie (Western Australia) in August 2010.

Other work in this project included the development of a database of relevant quantitative information that assists CSRP researchers in evaluating the overall benefits or impacts of the project outcomes. The focus of the database has been on electricity generation and transportation, as well as water and other mineral industry consumables.

Project Leader

David Brereton (University of Queensland)

Project Team

David Brereton, Glen Corder, Ben McLellan (University of Queensland)

Albena Bossilkov (Curtin University)

Roy Lovel (CSIRO)

Geoff Evans (University of Newcastle)

Chris Lund, Dick van Beers (GHD)

Amanda Pacecca, Gareth Pickering (BHP Billiton)

Damien Giurco (University of Technology Sydney)

Industry Champion

Philip Bangerter, Andrew Murphy (Hatch)

Students

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Project Leader

Albena Bossilkov (Curtin University)

Project Team

Frank Mofflin (BHP Billiton / Nickel West)

Sean Parker (Rio Tinto / HIsmelt)

Rod Lukatelich, Jaye Brennan (BP)

Genevieve Mannin (CSBP)

John Davis (Cockburn Cement)

Carmen Solorzano (Tiwest)

Craig Blume (Water Corporation)

Robin Howarth (Verve Energy)

Industry Champion

David Cooling (Alcoa)

Chris Oughton (Kwinana Industries Council)

Capturing Regional Synergies in the Kwinana Industrial Area (3B1 Extension)

This project provided ongoing support to the Kwinana-based industries with the identification and development of promising synergies (i.e. sharing and exchange of energy, water and re-use of by-products) and building to improve the overall eco-efficiency of the area. In addition, the project supported the Kwinana Industries Council (KIC) with the development and implementation of its Sustainability Roadmap. This Roadmap includes the development of regional sustainability indicators, strategies to achieve sustainability targets of the KIC, and engagement with internal (KIC members) and external stakeholders (e.g. government and community).

The project was overseen by an Eco-efficiency Committee established in the Kwinana Industries Council with representation of major companies in the area (CSBP, Alcoa, BP, Tiwest, Nickel West/ BHP Billiton, Water Corporation, Verve Energy, and HIsmelt). The research also contributed to the development and trialling of a regional eco-efficiency opportunity assessment methodology, the evaluation of synergy technology needs and opportunities, and the documentation of case studies.

The resource input-output database for the Kwinana Industrial Area was updated to the final version. The outcome of the evaluation of synergy opportunities was submitted to the KIC in April 2009 and the industry partners provided the team with a list of synergies that are most likely to be supported by the majority of the KIA industries. Investigation into the potential for a 5 gigalitre desalination plant utilising waste heat was the chosen synergy opportunity, which was investigated/assessed as the "Detailed Scoping Study into Evaporative Water Supply/Treatment System in the Kwinana Industrial Area (125)" project below.

Project Leader

Albena Bossilkov (Curtin University)

Project Team

Wahidul Biswas (Curtin University)

Industry Champion

David Cooling (Alcoa)

Chris Oughton (Kwinana Industries Council)

Detailed Scoping Study into Evaporative Water Supply/ Treatment System in the Kwinana Industrial Area (125)

This project undertook a scoping and pre-feasibility study into an evaporative seawater desalination system in the Kwinana Industrial Area south of Perth, utilising energy and moisture contents of industry flue gases. The first stage included a baseline assessment on the available desalination and evaporative water treatment technologies, followed by a review of the possible treatment/supply options in Kwinana. This stage also covered stakeholder engagement and the development of an issues paper on how a seawater desalination plant, driven by industry flue gases, would fit within the deregulation of the water supply market. The aim was to identify promising treatment scenarios which could attract industry, government, and community support.

This study was completed in December 2009 and the Kwinana Industries Council Eco-efficiency Committee will consider the next phase of the project following the closure of CSRP.

Project Leader

Albena Bossilkov (Curtin University)

Project Team

Michele John, Noraisha Oyama (Curtin University)

Industry Champion

David Cooling (Alcoa)

Chris Oughton (Kwinana Industries Council)

Detailed Scoping Study into Potential Effluent Synergies in the Kwinana Industrial Area (126)

This project aimed to further enhance synergies between industrial effluents and water supplies in the Kwinana Industrial Area (KIA) south of Perth, thereby improving the overall water efficiency in the area without compromising on process quality and control, and health and safety. The first stage of the project included an assessment of the current "fit for purpose" water use and water demands in the KIA, and the establishment of "fit for purpose" quality criteria. There was also a review of the current (inter)national and regulatory environmental and health and safety requirements in order to assess the technical feasibility of using secondary treated wastewater from the Sepia Depression Ocean Outfall Landline (SDOOL) for selected processes, such as cooling towers, slurry transport and dust suppression. The aim was to come up with promising treatment scenarios which meet these quality criteria and have anticipated industry, government, and community support.

This study was completed in December 2009 and the Kwinana Industries Council Eco-efficiency Committee indicated that the continuation of the project will be considered after the closure of CSRP.

East Rockingham Wastewater Treatment Plant – Industrial Synergies Scoping Study (131)

The project focussed on maximising the industrial synergies from the development of the wastewater treatment plant (WWTP) at East Rockingham. The Rockingham Industry Zone (RIZ) is the last heavy industrial site in the Perth metropolitan region and therefore of strategic importance to Western Australia. The WWTP should be regarded as a major opportunity to serve as an anchor tenant to attract synergistic businesses, rather than viewing the WWTP as a constraint in the development of the area.

This project showcased the commercial application of the regional synergies research program of CSRP. It was the first time that a new major utility being developed in the Kwinana Industrial Area (KIA) was evaluated for synergy opportunities. The project outcomes have the potential to lead to several synergies around the proposed treatment plant and existing and new industries in the KIA. The project also enabled a relationship to be developed with new partners, LandCorp and Water Corporation, which may lead to other research (such as feasibility studies of selected synergy opportunities) in the longer term.

The project confirmed the great potential for new synergies emerging from the proposed East Rockingham WWTP. Over 20 by-product, utility, supply, and service synergy opportunities were identified that involved the WWTP and existing and future industries in the RIZ and the KIA. The most promising synergy opportunities were the:

- Reuse of treated effluent by industries within the Rockingham Industry Zone and Kwinana Industrial Area;
- Co-processing of biosolids with other organic and inorganic resources;
- Managed aquifer recharge of treated effluent from the East Rockingham WWTP.

The odour footprint assessment undertaken as part of this project resulted in a set of review criteria to assist Water Corporation and LandCorp in deciding which industry types could or should not operate within the odour footprint of the wastewater treatment plant. The project delivered implementation plans to assist with the further development of the synergy opportunities identified and the odour footprint assessment. Both LandCorp and Water Corporation expressed their appreciation for the project report and results.

Concept design of the East Rockingham Wastewater Treatment Plant and its proposed location in close proximity to the Rockingham Industry Zone. © Water Corporation and ERM.

Project Leader

Dick van Beers (GHD)

Project Team

Doug Edgar, Bill Grace, Chris Lund, Emiko Watanabe (GHD)

Tom Grigson (Department of State Development WA)

Chris Brady, Alistrair Trethowan, Luke Willcock (LandCorp)

Frank Kroll, David Swallow (Water Corporation)

Industry Champion

Chris Oughton (Kwinana Industries Council)

Project Leader

John Rankin (CSIRO)

Industry Champion

Philip Bangerter (Hatch)

Minerals, Metals and Sustainability: A textbook for the future (124)

Future graduates for the minerals industry will not only require in-depth technical and scientific understanding of their fields (such as geology, mining and metallurgy) but, increasingly, they will also need knowledge of how their discipline relates to other technical disciplines and how the whole relates to sustainable development. While there are many books on geology, mining and metallurgy, at both elementary and advance levels, there are no technical books that provide a multi-disciplinary approach which integrates the physical and earth sciences with the social sciences, ecology and economics.

The end result of the project will be an undergraduate level textbook tentatively titled "Minerals, Metals and Sustainability – A textbook for the future". The Project Leader drafted the chapters, which were then reviewed by "key" readers (a mixture of experts from CSIRO, industry and universities) and then revised by the Project Leader. The text is written in three sections in a logical sequence: 1) Introduce readers to the concept of the earth as the source of all materials, how materials are utilised in society (with particular focus on inorganic materials) and the issue of sustainability in relation to finite resources; 2) Examine two important classes of materials – metals and cement – in detail; and 3) Address the sustainability challenges.

Progress in 2009/10 has been good. The final chapter has been written, with the complete draft completed in August 2010. Eighty percent of the figures have been prepared to publication standard.

Extensive revision and restructuring of earlier chapters was done in parallel with writing new chapters and the overall quality was continually improved. CSIRO Publishing has arranged for external refereeing and in parallel has sought an international co-publisher. After refereeing, and changes made by the author as appropriate, CSIRO Publishing will engage an editor to check style, spelling, references, etc and prepare an index. It is anticipated that type setting will be done in January/February 2011, followed by checking of the proofs (by the author) then printing. Anticipated release of the textbook is June 2011.

Project Leader

Goen Ho (Murdoch University)

Project Team

Mark Germaine (CSBP)

Industry Champion

Chris Oughton (Kwinana Industries Council)

Students

Robert Cocks, Mario Schmack (Murdoch University)

The ultrasonic meter used for site water meter calibration during the water audit at the Jundee mine © R. Cocks

Water Auditing for Improved Water Management in the Resource Processing Industries (106)

Water is an essential input to industrial processes and demand by industry is increasing due to growing industrial activities – and water auditing is a powerful tool for water management. In a water audit, the water quantity and water quality are determined for all water inputs and outputs of an industrial process and associated operations (e.g. offices and amenities), including stormwater and any reuse streams. An important outcome of a water auditing exercise is a list of recommendations for water conservation with options clearly identified and payback period calculated for the most promising options.

Water auditing has been practised in various forms, levels or intensity in the past, but has recently been made systematic, structured and rigorous in a text authored by Prof Goen Ho and published by the International Water Association, London. This project started in July 2009 and aimed to improve water use efficiency of industries in Kwinana through the use of a Water Auditing tool.

A water audit of Newmont's Jundee Goldmine was conducted and covered all aspects of the operation and included water sources, distribution and water quantity and quality of raw water abstraction, dewatering, tailings decant and seepage recovery processes. As part of the review process from water audits carried out in 2008, comparative water audits of the Jundee Goldmine and Jundee Village water circuit were performed in 2009. The findings illustrated how Jundee can become more water efficient by running simulations at systems level baselines including alternative options in site water distribution given site needs and efficient layout of water inputs and stores.

Robbie Cocks, a PhD candidate at Murdoch University, was awarded "best paper" during the proceedings of the Goldfields Environmental Management Group conference in Kalgoorlie during May 2010. Four Newmont gold mine case studies underpin the water auditing techniques developed in the thesis. Applications of process, non-process and domestic (village accommodation) were carried out to showcase a broad approach towards water efficiencies and water conservation in goldmining practises.

Energy Efficient Liberation and Comminution Program

Program Leader: Prof Malcolm Powell (University of Queensland)

The crushing and grinding of mineral ores is a major consumer of energy in many mineral processing plants. CSRP's research in this area has developed powerful models to determine the most effective way of liberating the target mineral from a given ore body. Application of this modelling will improve existing operations and allow new machines and flowsheets to be developed more cheaply and quickly than currently possible.

This program built on the ways identified in the foundation project "Energy Efficient Liberation and Comminution" to reduce total comminution energy at existing sites by 20 percent or more. Achieving this target will typically require taking advantage of more than one of the opportunities which have been identified.

This program included projects in the areas of High Pressure Grinding Rolls (HPGR), banana screens, mill charge monitoring and coarse liberation. A high level of success has been achieved in applying advanced computational techniques to modelling of comminution devices – the tools in use are at the forefront of the technology worldwide. Demonstration projects were run to take the most promising outputs of the program into pilot or industrial scale trials that tested, validated and quantified the predicted benefits.

The work was performed via a set of collaborations, as no single organisation has sufficient breadth to undertake the complete project. These collaborations were between the CSIRO, University of Cape Town, and the Julius Kruttschnitt Mineral Research Centre (JKMRC) at the University of Queensland.

CSRP's role, therefore, has been as an enabler and has resulted in some notable achievements – including the appointment of a Chair in sustainable comminution to provide oversight to the numerous projects; contribution to the world's most sensitive Positron Emission Particle Tracking facility; and significant input into the design and deployment of the innovative JK Rotary Breakage Tester.

CSRP's research has built on the capability of long-standing comminution research and has enabled a number of step change improvements to be implemented by industry. The strong collaborations will continue beyond the term of CSRP – further developing and implementing the research outcomes.

Program Highlights

- The JKRBT has provided unique data sets of breakage over wide energy ranges and rock sizes that are challenging the existing best breakage models and will form the best input yet available to mechanistic comminution models.
- PhD student Zeljka Pokrajcic won the "2010 Vittorio de Nora Prize for Environmental Improvements in Metallurgical Industries" awarded by The Minerals, Metals, and Materials Society.
- Prof Powell appointed to the steering committee of Positron Emission Particle Tracking (PEPT) facility in Cape Town, South Africa.
- A world first slurry model has coupled fluid flow and solids flow and has been used to analyse the slurry flow in a tower mill.
- Fine ore particles have been included in the simulation of a laboratory-size ball mill to explore what these do to the flow and what breakage environment they experience – computationally extremely challenging and the first study of its type.
- Full plant scale surveys and pilot plant campaigns were adopted to collect data for the Run-of-Mine ball mill operations – to deliver a model that can be used for both optimisation and design studies.
- Demonstration of the inadequacy of company accounting systems in addressing energy consumption and production of carbon dioxide.
- Mathematical model to predict the breakage of mono-sized particles contained in unconfined beds – has been very successful in describing the breakage of a variety of materials under variable breakage conditions.
- Results indicate that depending on the textural features and mechanical properties of the ore, as well as blast variables, it is possible to produce an ore fragment size distribution to optimise coarse liberation.
- Highly-sophisticated models of banana screens can now be solved with more than 200,000 particles in reasonable computation times, and predict separation performance and flow through the screen.
- Results show that there is a limit to the number of times that an ore can be crushed efficiently by HPGRs in series – indicating a limit of two HPGR passes for efficient grinding of hard ores.

Prof Malcolm Powell visiting Europe's deepest pit and the world's largest mill. © M. Powell

Project Leader

Malcolm Powell (University of Queensland)

Project Team

Neville Plint (Anglo Platinum)

Brian Smith (BHP Billiton)

Chris Goodes (Rio Tinto)

CSRP Comminution Program Leadership (67)

For a significant research effort on one of the industry's most important processes, top class leadership is required to realise the full potential of the Energy Efficient Liberation and Comminution Program (probably the largest effort on this topic worldwide). CSRP's Governing Board encouraged the appointment of a professional research fellow to lead the Comminution Program and provide oversight and ensure the maximum benefits to the sponsors and the industry as a whole. This culminated with the appointment of Prof Malcolm Powell as the inaugural Chair in Sustainable Comminution based at the University of Queensland.

Several projects were developed within CSRP to link areas of research and to take advantage of positive findings that have arisen from CSRP projects. These focussed on energy efficient circuits through adapting existing circuit equipment and expanding circuits in novel manners.

There were several areas of activity during 2009/10:

Three new staff members were involved in CSRP's project work and Dr Simon Michaux was mentored to take over the mineral processing comminution undergraduate course at the University of Queensland. A visiting student and two vacation students were supervised in core projects and one of the previous students, Tom Perkins, later joined the CSRP staff as a researcher.

Prof Malcolm Powell provided general leadership in the comminution and sustainability areas, with a leadership/guidance role in over 20 sub-projects and extensive input into continuing programs that build on CSRP's outputs:

- Site work on linking mill performance to mill liner profile and on modelling the wear of mill liners.
- A number of weeks were spent on Australian and international mine sites delivering training on process control and optimisation, conducting practical site demonstrations – such as operating the mills over extended periods – collecting data for and developing improved process optimisation techniques.
- Supervised work on human interface control was aimed at improving the operation at the working face of mine sites – it is the operators who have the influence of actual operating efficiency.
- The construction of an abrasion testing mill has been completed and the testing of five ore types collected from associated full-scale survey work will be commencing shortly.
- Leader of the AMIRA P9O comminution research program.
- Co-supervising a student and postdoctoral fellow through the links developed within the Sustainable Minerals Institute at the University of Queensland.
- Technical advisor for the Comminution 2010 conference in Cape Town, attracting the largest conference attendance ever.
- Guest editor for the 2010 comminution special edition for the Minerals Engineering Journal – the world's highest ranked minerals processing journal.

For the third year, the topic of comminution was promoted through running an interactive practical course at the University of Queensland that utilised a wide range of equipment, with input from a range of expert JKMRC personnel, at the JKMRC pilot facilities.

Progress is being made in linking sustainability measures with plant operation through the project conducted by the University of Queensland research student, Daniel Tuazon. This has formed a first test case study that is demonstrating the gap between company policy and application in operations. Positive outcomes are arising from utilising sustainability measures to enhance profitability while addressing environmental and social issues.

Various publications on energy efficient and water efficient circuits were produced under this project, with over 12 publications in 2009/10.

Prof Powell was chair of the Sustainable Minerals Institute research committee and a member of the University of Queensland research committee. He was an invited plenary speaker at the European Comminution and Classification Symposium held in Helsinki, Finland during September 2009; and was involved in re-establishing the International Comminution Research Association (ICRA) and then elected as the international chairman. Prof Powell was appointed to the steering committee of Positron Emission Particle Tracking (PEPT) facility in Cape Town and was organiser of the highly successful ICRA workshop on PEPT, held in Cape Town in April 2010.

Eco-Efficient Liberation and Comminution (2B1 Extension)

This project built on the highly successful foundation project and identified and tested ways to reduce the total comminution energy at existing mine sites by 20 percent or more. Specific demonstration projects were targeted, along with areas that were identified as requiring further development in order to capitalise on the outcomes of the foundation work.

The original base version of the Unified Comminution Model (UCM) was expanded to include incremental damage and two major modes of abrasion. This was tested against pilot mill data. A 1.8 metre diameter abrasion mill was constructed, allowing it to be used as a new abrasion testing device.

The JK Rotary Breakage Tester (JKRBT) and the University of Erlangen mini-breakage tester were used to characterise the breakage of three ore types over a wide range of energy – from very low surface damage to incremental breakage to single hit breakage, and on a wide range of rock sizes from 50 microns to 50 millimetres. These unique data sets of breakage over wide energy ranges and rock sizes are challenging the existing best breakage models and will form the best input yet available to mechanistic comminution models. Findings are that the current models are inadequate and do not hold over this wide range of conditions. Further research is required to study alternative models.

Three-dimensional Discrete Element Method (DEM) simulations were used to analyse the dry particle flow in tower and ball mills. Results showed that tower mills are potentially more energy-efficient than ball mills. However while ball mills are likely to be less-efficient in energy terms, they are also going to be very "forgiving" in terms of tolerance to variations in ore feed size distribution and hardness.

A world first slurry model has coupled fluid flow (Smoothed Particle Hydrodynamics) and solids flow (DEM) and has been used to analyse the slurry flow in the tower mill. The same technique has been applied to the pilot mill, with outcomes of direct relevance to mill operation and slurry flow control.

Fine ore particles have been included in the simulation of a laboratory-size ball mill to explore what these do to the flow and what breakage environment they experience. This is computationally extremely challenging and the first study of its type. Results will open the door to fundamental grinding simulations and studies of the micro-environment in milling devices – getting to the core of energy transmission.

A DEM study of the separation performance of double-deck banana screens led to interesting insights. Using realistic non-round particles gave an opportunity to seriously explore industrial-scale screen performance in much more detail than is possible with traditional testing techniques – although good quality survey and wear measurements will be essential for verification of the DEM models.

PhD student Zeljka Pokrajcic won the *"2010 Vittorio de Nora Prize for Environmental Improvements in Metallurgical Industries"* awarded by The Minerals, Metals, and Materials Society. She attended the award ceremony and presented her work in Seattle in February. Dr Pokrajcic has been researching ways to minimise the energy usage of crushing and grinding (comminution) circuits. Her approach involves reducing the mass of material in the comminution circuit by rejecting coarse-sized, commercially worthless material before milling, as well as using more efficient crushing and grinding equipment. She also used modelling and ore characterisation technology developed at the JKMRC.

Three CSRP-funded students completed their research: Zeljka Pokrajcic (PhD), Fiesal Musa (PhD), and Mike Larson (Masters).

Other significant outcomes from this project include:

- Gary Delaney, a Postdoctoral Fellow at CSIRO, gave a keynote address to the 9th World Congress on Computational Mechanics entitled "Novel applications of DEM modelling comminution processes".
- Demonstration of the inadequacy of company accounting systems in addressing energy consumption and production of carbon dioxide.
- Initiation of a program in flexible circuit design to enable dramatic reductions in overall circuit energy consumption.
- Initiation of the modelling of mill liner wear and its influence on milling efficiency.
- A new version of the Ergun equation for flow through a porous bed has been developed for flow through a tumbling shearing porous bed, as in the charge of a mill – an example of "ground breaking" research.

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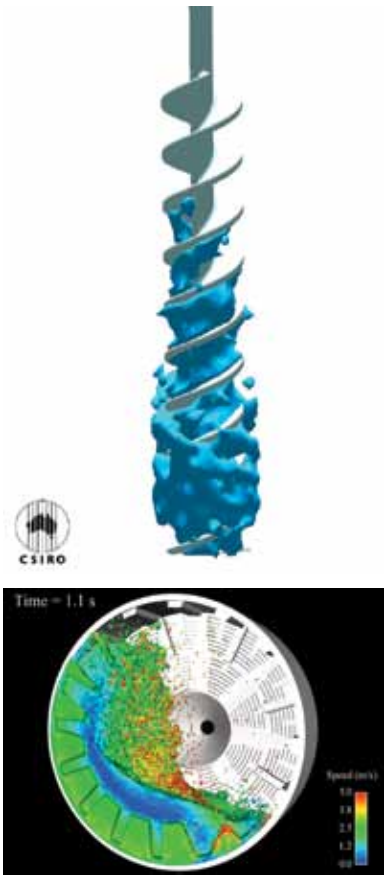

World-first slurry model used to analyse slurry flow in the tower and SAG mill. © CSIRO

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Rock samples used for impact breakage testing and model development.
© N. Djordjevic

Comminution Program (AMIRA P9O) (2B2 Extension)

The vision of the AMIRA P9O project is to improve comminution, classification and flotation performance on sponsor sites through modelling, simulation and characterisation of particles and their process environments, and through training and transfer of skills and technology to the industry. Based on the past achievements of AMIRA P9N, the AMIRA P9O project and associated projects aim to develop an integrated, multi-component simulator structure of the entire comminution, classification and flotation process chain, and multi-component models of the unit operations. The project will also deliver new measurement and characterisation (and other) tools, which will considerably enhance the ability to predict and improve plant performance.

The goals of this research are to incorporate mineralogy and rock type along the process chain through multi-component modelling, integrate simulation of comminution, classification and flotation circuits, improve understanding of specific comminution processes and understand physico-chemical effects on floatability (reagents, grind/regrind).

CSRP participants have been working with AMIRA project participants on several areas:

Work continued on a multi-component model that can predict the distribution of minerals in the broken fragments of ore, given the size distribution and grain size distribution of the minerals in the parent rock. Three surveys were conducted at Kanowna Belle plant and a model of the grinding circuit was developed. Analysis of the particles using cone beam tomography is underway, with the outcome to be validated from measurements using MLA. Development of the breakage model is also underway.

CSRP's work on a multi-component Autogenous Grinding/Semi-Autogenous Grinding (AG/SAG) mill model has previously proved the hypothesis that the breakage rates, mill load and throughput are affected by the proportion of the different components in the feed. Development of the model incorporated feeds with different hardness and measured the breakage of a hard component (mineral) and a soft component (mineral) in the SAG mill environment.

An integrated pilot plant campaign was carried out at the Frank Pilot Plant testing facility of Anglo Platinum in November 2009. A total of six runs were performed in order to generate a good data set to validate the models and testing procedures. The application of the model is being studied using data from this pilot plant study.

A Run-of-Mine (RoM) ball mill project is developing a model for this type of mill. There is little information on the best operating practices for the RoM ball mill and the influence of key operating variables on throughput and grind is not well understood. Both full plant scale surveys and pilot plant campaigns were adopted to collect data for the RoM ball mill operations. The main deliverable is a model that can be used for both optimisation and design studies. Site work was carried out at Lonmin and Anglo Platinum operations in South Africa. Ore characterisation tests for the base case survey were performed at the JKMRC and the results were incorporated into the database for RoM ball mill modelling.

A mathematical model to predict the breakage of monosize particles has been developed and has been very successful in describing the breakage of a variety of materials under variable breakage conditions (ball size, impact energy and bed configuration). This model allows the mechanistic model of the ball to take into account explicitly the effect of several physical variables, with little or no need for model fitting.

Further development of these models, test work and surveys will continue beyond the term of CSRP, through the support of AMIRA.

Characterisation of Rock Mass for Liberation at Coarse Sizes (2B8)

The grain size distribution of a mineral within an ore body determines to a large extent the ease with which the mineral can be liberated – large grains are liberated at comparatively large particle sizes. Prior experimental results and literature reviews have demonstrated that coarse particle liberation is a function of the geological and structural properties of the rock, as well as the methods of blasting and rock crushing. Coarse liberation prevents having to put all rock through fine grinding and flotation separation, which has multiple environmental and economic benefits – in particular lower energy, water and reagent requirements and avoiding unnecessary exposure of unwanted components (for example sulfur bearing material that could oxidise and create liabilities from acid rock drainage).

This project aimed to evaluate and quantify coarse particle liberation for ores from the mines of the participating companies, and to determine blasting and separation/screening parameters which are likely to maximise coarse particle liberation of the valuable minerals. The project adapted and developed appropriate methods to assess the degree/effectiveness of coarse liberation and subsequently developed and applied a customised rock fragmentation model (using Finite Element Method code) to predict coarse liberation under different blasting and rock crushing parameters. The project also sought to identify and evaluate the effectiveness of alternative separation methods to separate ore from gangue at coarse particle size.

The results from the project indicate that depending on the textural features and mechanical properties of the ore, as well as blast variables (e.g. mass of explosive per hole, blast hole placement etc) it is possible to produce an ore fragment size distribution to optimise coarse liberation.

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Rock samples used for impact breakage testing and model development. © N. Djordjevic

Demonstration of Banana Screen Modelling Capability (2B11)

Large banana (multi-slope) screens are widely used in the iron ore industry to perform separation of ore from fines because of their high capacity over the older-style flat-deck screens. However relative to the older screen designs, banana screen efficiency is poorly understood and it is difficult to optimise screen performance because of the large number of factors that affect its performance. There is a need for modelling capabilities that can be used to predict screen performance with a view to optimising separation efficiency, capacity and wear. This project demonstrated to industry participants the Discrete Element Method (DEM) / Virtual Comminution Machine and scale modelling capabilities of an industrial banana screen application.

Due to lack of access to full-scale site data, the JKMRC pilot screen (of 1m length) was modified to provide high-quality validation data for the DEM modelling. This data was then supplied to CSIRO Mathematics, Informatics and Statistics to match with the DEM modelling.

DEM predictions of flow and separation efficiency using spherical particles were compared to experimental data in order to assess their accuracy. Reasonable agreement was for low feed rates, however at higher feed rates, very significant deviations between the experiment and the simulation emerged.

The DEM study of the separation performance of double-deck banana screens lead to interesting insights. Using realistic non-round particles gave an opportunity to seriously explore industrial-scale screen performance in much more detail than is possible with traditional testing techniques – although good quality survey and wear measurements will be essential for verification of the DEM models.

A full-scale screen was modelled with DEM and then with a combined DEM and Smoothed Particle Hydrodynamics to model both the particles and the fluid flow. At mid-range speed (peak acceleration of 5g), the separation performance of the top deck is good and a deep bed quickly builds up on the bottom deck.

DEM simulation of full-size two deck banana screens is now feasible. Models including the full geometry of the screen, its motion, and the shape of the particles can now be solved with more than 200,000 particles in reasonable computation times, and predictions of separation performance and of the flow through the screen are quite realistic.

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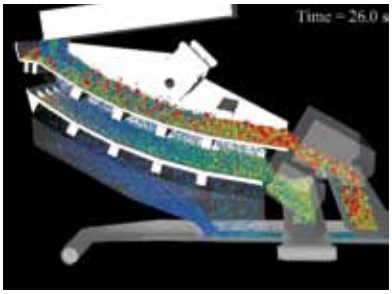

Particle distribution on the screen during a vibration cycle for a particle bed that is in equilibrium; particles are coloured by their size. © CSIRO

Project Leader

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Flotation of Coarse Particles (110)

The recovery of sulfide minerals by flotation is influenced by the particle size. Particles in the range 30 to 120 microns generally float rapidly, but at each end of this range, the rate decreases markedly as particles become smaller or larger. For flotation to occur, a particle must be firmly attached to at least one bubble. The bubble exerts a lift force on the particle, through the action of surface tension acting on the three-phase contact line on the surface of the particle. Gravity acts in opposition to the surface tension force. With pure homogenous particles of regular geometry, the attachment force depends on the particle geometry and the contact angle. In real systems the particles are seldom homogeneous, and are usually only partially liberated. The degree of liberation generally declines as the particle size increases. Thus when considering the flotation of coarse particles, it is essential to take into account the degree of liberation, the shapes of the hydrophobic mineralisation zones on the surfaces of the particles, as well as the effective contact angle of the composite.

In this project, samples of different ore types were crushed and ground in different ways so as to alter the liberation characteristics. The ground ore was subjected to flotation in the fluidised bed cell. Particles from feed, flotation product and tails were examined by Mineral Liberation Analysis or Cone Beam Tomography, on a size-by-size basis and the recovery were then correlated with the degree of liberation.

Samples of lead/zinc ore have been crushed and separated into size fractions and a test protocol for coarse flotation was developed for the fluidised bed flotation cell. The test used galena particles in the same size range plus quartz as a gangue mineral to mimic the known lead concentration of the actual ore. The particle size that is recoverable by the new device is about ten times larger than that recoverable in current technologies – however there was an abrupt drop in recovery at about 900 microns.

It was necessary to reconstruct the machine to avoid very large particles from being trapped selectively in a part of the cell. A satisfactory reagent scheme was also developed, together with a method for simple determination of the recovery on a size-by-size basis. A method for measuring the effective contact angle of the floatable particles was developed.

Analysis showed that there was a significant mismatch in the mass balance between particles in the feed and particles reporting to concentrate and tailings. In effect, coarse particles were found to accumulate in a region of the cell that effectively removed them from the flotation process. Accordingly, the design of the cell was altered to overcome this problem. Sized samples of product, feed and tails were sent to the JKMRC for analysis and the results discussed at a sponsors meeting in August 2010.

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Chris Goodes (BHP Billiton)

HPGR Triple Pass Circuit Concept (2B10)

The main aim of this project was to dry process the ore to near ball mill product size and to accurately determine the energy required to achieve this. A three-pass High Pressure Grinding Roll (HPGR) flowsheet was expected to be more energy efficient than current Autogenous Grinding/ Semi-Autogenous Grinding/ball mill circuits and was tested at pilot-scale on several ore types. The flowsheets were compared on direct and embodied energy consumption and on an economic basis (capital, consumables, maintenance) against current circuits.

Test work was carried out on three samples using the 0.75 metre diameter and 1.0 metre diameter Köppern HPGR units at AMMTEC in Perth. This choice allowed a feed size of around 32 millimetres top size which is comparable to the feed size used in industrial HPGRs and therefore a more meaningful scale than the smaller scale HPGR usually used for HPGR experimental work. The product from the HPGR grinding after three passes was then milled using a laboratory mill to determine its grindability to a size of 150 microns. Energy measurements were made at each size-reduction step.

The results show that there is a limit to the number of times that an ore can be crushed efficiently by HPGRs in series. Following a reasonably large size reduction ratio on the first pass and second passes, a drop in grinding efficiency is experienced on the third HPGR pass – indicating a limit of two HPGR passes for efficient grinding of hard ores.

Bauxite Residue Program

Program Leader: Dr Evan Jamieson (Alcoa)

Production of alumina from bauxite ore results in the production of bauxite residues that might further be processed into valuable by-products thereby reducing the quantity of residue requiring final storage. These storage areas occupy a significant area of land and require final closure, rehabilitation and ongoing management. To reduce the volumes of this residue, researchers are also developing beneficial uses for bauxite residue in construction and agriculture with potentially very significant ecological advantages.

This program also investigates the cost-effective recovery of the valuable components in "red mud" using a variety of processes. Trials of promising products are underway in field demonstrations, along with broad-based sustainability assessments. Commercialisation frameworks and market assessments are also being developed for these products.

CSRP has developed a concept called ReSand® where sand sourced from recovered materials is compared to conventionally sourced quarry sand. The source of sand which is assessed as having the lowest ecological footprint or impact can then be designated as ReSand®. This gives developers, regulators and the community an assurance that the use of these residue materials is in fact the best outcome for the environment and for society.

Various mineral processing operations produce large volume residues that are currently disposed of in dedicated facilities. The sand fraction from various residues, such as bauxite residue, fly ash, cement and lime kiln dusts, gypsum, iron making slags, mineral sands by-products and gold processing tailings, may serve as a useful by-product in various commercial applications if diverted prior to normal disposal. Production of this by-product sand to a standard would be branded trade mark ReSand®. One example of such a by-product is the coarse fraction of the bauxite residue produced by Alcoa in its Western Australian alumina refineries called Red Sand™. By-products from mineral residues also have applications in the agricultural industry. The existence of two alternative sources of acid soil ameliorants, both of which are already effectively in storage and therefore do not incur high costs for extraction, may now provide a highly beneficial alternative to mining depleting lime reserves. The recovery of useful by-products from mineral residues has a range of potential benefits including:

- replacement of increasingly scarce supplies of quarry sand;
- reduction in the clearing of natural bushland for sand quarries; and
- reduction in the demand for expensive waste residue containment facilities.

These benefits can lead to reduced costs, less energy/water use and lower greenhouse gas emissions.

Program Highlights

- Trials in road construction and environmental results for the use of ReSand® are very encouraging, and are showing ReSand® to be a competitive source of construction sand.
- A nutrient stripping filter constructed from bauxite residue and gypsum has been effective in controlling the pH and removing phosphorus and other contaminants from surface water.
- A public review on the use of bauxite residue as a soil amendment has shown strong public support for the by-product.
- Alternative lime products made from bauxite residue worked as well or better than crushed limestone and lime sand in raising soil pH, with no deleterious effects on plant life.

Demonstration Trial for ReSand® (129)

Recent research has identified methods of separation of bauxite residue, its neutralisation through carbonation and its ability to be washed low in salt. Alcoa has produced substantial tonnages of washed and carbonated material (Red Sand™) for substitution of virgin mined sand in various trial applications. Laboratory testing in 2006 showed that ReSand® could potentially provide both commercial bulk fill (embankment construction) and pavement material to the civil construction industry, replacing the commonly used virgin mind sand and limestone. This project focussed on two potential applications: the top-dressing of grass fields; and fill in road construction.

The first application of sand for top-dressing required a staged roll out and trial. Following significant leaching evaluation, a small trial took place and culminated in the large-scale application of sand for top-dressing of an oval. Monitoring was carried out on dust, regrowth rate, plant nutrition and uptake of metals, along with drainage water assessment.

The second application of sand was for construction of an external road. The physical properties of the sand were reviewed by Main Roads WA and the results determined where in the road profile the sand can be used – in this case the sand has been used in place of crushed lime stone. The construction works were conducted by Southern Roads Services, the contractor responsible for delivering all maintenance and minor construction works in the state road network for the south west region of Western Australia. It was reported by the contractor that the ReSand® was easy to work and compact.

Long-term monitoring of leaching and the road structure has been carried out under the CSRP project "Monitoring of Red Sand ™ used in Greenlands Road Upgrade" (128).

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The nutrient-stripping filter constructed with bauxite residue has been effective in removing contaminants from surface water entering the wetland. © DAFWA

Demonstration of Infiltration Barrier Utilising Bauxite Residue (130)

The overall aim of the project was to install and monitor a nutrient stripping device to retain nutrients from agricultural land and to assess the feasibility, effectiveness and potential impact of using bauxite residue (for nutrient attenuation) to improve the quality of runoff water.

The Southern Gateway Alliance planned to capture nutrient runoff from agricultural land through a constructed wetland to reduce the nutrient concentration, particularly that of phosphorus. The strategy was to install a Storm-max system (designed by the Wallis Group) incorporating bauxite residue and place it at the southern end of the constructed wetland. Water would flow through the Storm-max system, stripping the nutrients, and into a constructed settling basin. Bauxite residue has a high phosphorus adsorption capacity and this will enable phosphorus to be captured. Road runoff would be captured and treated separately to remove suspended solids and floating matter including hydrocarbons.

During 2009/10, a filter was constructed in an artificial wetland near Coolup in Western Australia. The filter was was constructed from a mixture of native sand, limestone and bauxite residue (with 10 percent phosphogypsum). This study assessed the effectiveness of the removal of nutrients and measured the impact of the filter by comparing the concentration of any contaminants in the filtered water with established standards, background levels and contaminants in runoff from the highway. The total amount of water that passed over the outlet weir was approximately 20,000 cubic metres.

The filter has been effective in removing phosphorus. It is anticipated that with improved surface water access into the wetland, higher concentrations of phosphorus will enter the wetland in the second half of 2010, saturating the upstream portion with nutrients and water, and enabling a better test of this aspect of the trial as well as determining the lifetime of the filter.

Without the wetland, the nutrients entering the drain downstream of the wetland would have been much higher – as demonstrated by the high concentrations draining from the farmland into the inlet of the wetland.

An important subsidiary aim of this project was to determine the nature of any contaminants that may be leached from the filter in the short and long term. The leaching from the filter of constituents with potential environmental concerns was examined and it is unlikely that release from the filter poses any further risk than what is already occurring in the Mayfield drain and elsewhere.

The ultimate outcomes from this project will:

- Demonstrate that the filter does not cause upstream flooding;
- Foster increased public confidence and acceptance of bauxite residue use; and
- Act as a driver for more reuse applications.

The project participants will continue the trial beyond the term of CSRP to determine whether the trends in nutrient removal and constituent behaviour continue in the second year.

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Monitoring of Red Sand™ used in Greenlands Road Upgrade (128)

The use of coarse bauxite residue as a replacement for virgin mined sand in road construction is a key achievement for large scale use of mineral by-products. The physical evaluation of bauxite residue for use in the construction of a road was completed and the road prepared for construction. In the trial, more than 2500 cubic metres of sand was extracted from bauxite residue and used as road base to widen the Greenlands Road access to the new Perth Bunbury Highway near Pinjarra in Western Australia.

Once the road was completed in October 2009, monitoring of surface and ground water was undertaken to determine if there were any impacts from the use of bauxite residue compared to the impact of the "natural" (virgin mined) material. A detailed monitoring program was agreed. Monitoring of the drains also commenced prior to the road construction.

Initial construction data and subsequent testing was compiled into a final report. The results show that the ReSand® has proven to be an excellent embankment and subgrade construction material with strength properties that greatly exceed those of the normally used Perth sands. ReSand® is a strong improved subgrade or sub base material with a soaked Californian Bearing Ratio strength of 30 percent or greater, only requiring the minimum design thickness of basecourse material. ReSand® may also potentially replace limestone as a pavement basecourse material covered with a thin layer of gravel.

Water samples were taken in winter, when Perth receives more rainfall, and chemical analysis is expected to be finalised by October 2010. Finalisation of the report from Year 1, with included data from Year 2 as an addendum, is expected to be completed by December 2010 and delivered to the project participants.

For the next five years, pavement strength testing and visual inspections of the trial section of road will be conducted annually at the end of winter. After this time, the trial section will also be measured for roughness and rutting deterioration rates. The ultimate outcome will be for the ReSand® to be as strong as limestone for the construction of composite pavements, covered with thin gravel surfacing.

This project represents the monitoring program and is linked to CSRP project "Demonstrations of Red Sand™" (129). Monitoring will be carried out by the project participants beyond the term of CSRP.

"Monitoring of Red Sand ™ used in Greenlands Road Upgrade" (128).

Long Term Monitoring of the Impacts of Bauxite Residue (Alkaloam®) Application to the Peel-Harvey Coastal Plain Catchment – Sustainability and Risk Review (4A3 Extension 1)

This is an extension to the 4A3 project on the "Long term monitoring of the impacts of bauxite residue application to the Peel Harvey Coastal Plain catchment". The previous work involved implementing a catchment-wide research and monitoring program to investigate the effects of using Alkaloam® on the Peel-Harvey Coastal Plain, and the extent and duration of phosphorus retention achieved through its use. The extension work allows for a detailed Risk and Sustainability review to bring all documentation together for summary and incorporate stakeholder engagement for evaluation of Alkaloam®.

A report by the Department of Agriculture and Food WA on the work in the original 4A3 project was completed and issued to the Environmental Protection Agency in late 2006 for review. Monitoring of the Alkaloam® applications is continuing.

In 2008, CSRP commissioned environmental consultants URS and the University of Queensland's Centre for Social Responsibility in Mining (CSRM) to undertake a sustainability assessment on the use of bauxite residue as a soil amendment on agricultural land. The key objectives of this assessment were to evaluate the safety, effectiveness and value of bauxite residue, and understand current community perceptions of the product and attitudes to its potential commercialisation.

As part of the assessment, CSRP sought feedback on the report from key regional stakeholders. These comprise individuals or groups who participated in the community consultations undertaken by CSRM, regional service providers, agencies, or catchment authorities, local governments, and other interest groups.

To assist with the review, CSRP produced a comprehensive *Summary Report* outlining the study's key findings as well as an *Information Sheet* to provide stakeholders with further information on the review and the process for addressing any comments received. A public notice was run in local newspapers and the reports were made available on the CSRP website at www.csrp.com.au/projects/alkaloam.html Stakeholder feedback received by CSRP was distributed to the project team for response and/or inclusion in the final report.

Gaining stakeholder feedback was an important part of the sustainability assessment and helped CSRP ensure that the report was as comprehensive as possible and accurately reflected the interests of stakeholders. The final report was finalised by the end of October 2010 with the public comments included and is available on the CSRP website.

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Alternative Lime Source Trials (4A4)

Since being cleared for agricultural use, many of the Western Australian soils have acidified. Surface applications of lime and other neutralising amendments are the most common way to correct acidity. The use of alumina production by-products as "liming" ameliorants for agricultural soils affected by soil acidity presents an opportunity to alleviate the stress currently being placed on traditional lime sources and their reserves.

These trials investigated the effectiveness of two new agricultural lime materials in high rainfall pasture and medium rainfall cropping farming systems. The key performance indicators were the soil pH at surface and through the soil profile; soil exchangeable cation and sodium and aluminium levels; soil nutrient levels and Phosphate Retention Index; plant productivity; and plant tissue analyses.

The lime sources were compared with standard lime sand and crushed limestone at three locations in Western Australia – one located on a property near Busselton (used for beef grazing of clover/ryegrass pastures), and two in medium rainfall inland areas on the Merredin and Newdegate Research Stations (in a barley cropping system). Each site was assessed for a range of soil parameters before the application of the lime treatments. Lime treatments were applied before the expected onset of consistent winter rainfall. Drought severely impacted upon results and so potted plant trials were added to the project scope.

At the highest rate of application, fine bauxite residue (Alkaloam®) and bauxite lime residue both worked as well or better than crushed limestone and lime sand in raising soil pH – which answered the key question being asked. Alkaloam and lime residue at most sites worked to a depth of 10 centimetres.

While the soil pH did increase, there were no significant increases in pasture productivity or wheat yield for any ameliorant during the trial period. This was attributed to the initial soils not being limited by exchangeable aluminium, hence plant growth was not limited by existing pH.

Metal analysis of potted trial plant tissue samples indicated that there were no deleterious effects on the plants from using lime residue or Alkaloam. As with previous trials undertaken using Alkaloam, there was an increase in total aluminium in the soil but no associated increase in exchangeable aluminium.

Lime residue and Alkaloam® should both be seriously considered as alternatives for Western Australia's declining agricultural lime reserves. The use of nitrogenous fertilisers and leguminous pastures in Western Australian agricultural systems is likely to continue into the foreseeable future and this is likely to result in continued acidification of the soil resource base.

Given these trials were affected by drought conditions, it may be worthwhile establishing a field and glasshouse trial which is more directly designed to assess plant response to the ameliorants under controlled conditions. It is recommended that further, more detailed cost-benefit analyses of the use of these materials be undertaken in order to develop a realistic plan for their utilisation in the lime marketplace.

Geopolymer Program

Program Leader: Prof Arie van Riessen (Curtin University)

Geopolymers are a class of inorganic polymers formed by the reaction between an alkali and an aluminosilicate source. Variations in the ratio of aluminium to silicon, and alkali to silicon, produce geopolymers with different physical and mechanical properties. These materials have an amorphous three-dimensional structure that gives geopolymers certain properties, such as fire and acid resistance, which make them an ideal substitute for Ordinary Portland Cement (OPC) in a wide range of applications.

Many by-products produced by industry can be used as feedstocks for geopolymer, including fly ash from coal-fired power stations, mine tailings and bauxite residues. This program is investigating the microstructure of geopolymers and developing demonstration products for large scale applications of geopolymer concrete.

Using geopolymers to replace OPC in concrete structures has the potential to significantly reduce greenhouse gas emissions; use large volumes of industrial (waste) by-products; and increase resource efficiency by producing concrete products with longer service lives.

Program Highlights

- Second geopolymer concrete path laid at Curtin University using a blend of two Australian fly ashes.
- Beam time at the Advanced Photon Source in Chicago was awarded to conduct an analysis of precursors and geopolymers.
- Beam time was allocated at the Australian Synchrotron for two experiments to support PhD projects, namely fire-resistance of geopolymer (William Rickard) and reaction kinetics of geopolymer formation (Ross Willams).
- Comparison of selected sustainable development metrics for geopolymer concretes with Portland cement concretes using a newly developed sustainability metrics calculator.
- Geopolymer Foundation Ltd was officially registered and able to conduct business for the Geopolymer Alliance. The Alliance held its first meeting in early 2010. Thirteen members are registered.
- Ongoing partnership developed between Rocla and CSIRO to evaluate the materials requirements for future high-performance, low-profile geopolymer railway sleeper trials.
- Improved fire-resistance performance of thin geopolymer coatings.
- Increased understanding of the formation and identification of geopolymers – helping to inform the applied research using industry residues.

Geopolymer Concrete from Regional Waste Streams (4B1 Extension)

This project's overall aims were to develop the necessary chemical and structural understanding of geopolymers made from waste products. This information could then be used to capture a significant share of the ready-mixed and precast concrete market for a given industrial region. Research assessed the suitability of silica-bearing waste streams generated in any one geographical region, and helped determine the role that secondary metal ion constituents in the geopolymer process play on the kinetics of formation and resulting microstructure of geopolymers.

The project had a number of streams of work and included demonstrations of geopolymer concrete products:

Stream 1: Fundamental science of geopolymers

Stream 2: Demonstration Projects
(i) Premix geopolymer concrete
(ii) High performance geopolymer concrete railway sleepers
(iii) Thermal properties of geopolymers
(iv) Bayer residue geopolymers

Stream 3: Geopolymer Alliance

Stream 4: Geopolymer sustainability metrics calculator

Project Leader

Arie van Riessen (Curtin University)

Project Team

Dan Perera, Lou Vance, Phil Walls (ANSTO)

Kwesi Sagoe-Crentsil (CSIRO)

Craig Buckley, Alex Ciluzzo, Rob Hart, Temuujin Jadambaa, Melissa Lee, Hamid Nikraz, Brian O'Connor, Prabir Sarker, Daniel Southam, Kate Wright, Barry Whittington, Min Xie (Curtin University)

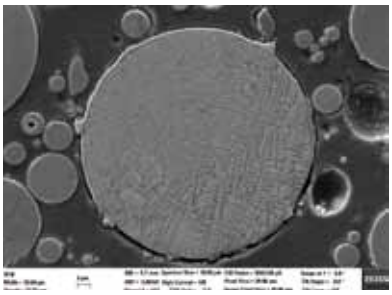
Evan Jamieson (Alcoa)

Industry Champion

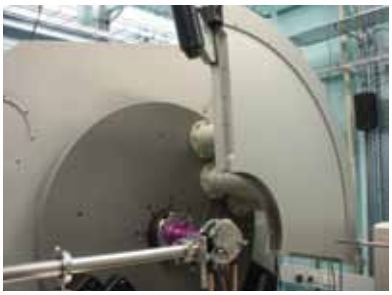
Greg Johnson (Rocla)

Students

Berlin Ciputra, Nigel Chen-Tan, Darryl Hole, Clinton Maitland, William Rickard, Kaveh Soltaninaveh, Shani Sperinck, Iestyn Williams, Ross Williams (Curtin University)



Scanning electron micrograph (SEM) image of Collie fly ash. © Curtin University



Ross Williams conducting experiments on the SAXS beamline; and the beamline with William Rickard's special purpose-built furnace. © Curtin University

Stream 1: Fundamental science of geopolymers

The work in this part of the project was ongoing for the entire term of CSRP and ran in parallel with the demonstration projects in stream 2.

An important aspect of the work was developing robust techniques to enable determination of the reactive component of precursor materials such as fly ash. A number of PhD students contributed to this by investigating the chemical reactivity of fly ash and determining the reactive component via x-ray techniques:

- Nigel Chen-Tan's PhD project focussed on the beneficiation of fly ash and an assessment of geopolymers made from the various grades of ash. It is clear that the geopolymer structure changes as more of the reactive component of the fly ash is made accessible to the alkali.
- As part of his PhD project, William Rickard collected diffraction data at the Australian Synchrotron. His experiment tracked changes in the geopolymer structure as it was exposed to a standard fire profile. William also had a special furnace purpose built so he could test small geopolymer panels (200 by 200 millimetres) exposed to standard fire profiles.
- PhD candidate Ross Williams completed two synchrotron experiments to conduct in-situ monitoring of the reactions that occur during the curing of geopolymer samples at 70 degrees Celsius. These novel experiments used the WAXS/SAXS beamline – a flexible x-ray scattering facility at the Australian Synchrotron.

Stream 2: Demonstration Projects

"Premix" geopolymer concrete

The second geopolymer concrete path was cast in November 2009 using a blend of two Australian fly ashes. As with Path 1, a number of hurdles were encountered but in the end the exercise was successful. Overall this was a very successful demonstration benefitting from the effective collaboration between CSRP Participants CSIRO and Curtin, with strong support from Boral.

High performance geopolymer concrete railway sleepers

This project investigated the design of high-performance, low-profile geopolymer railway sleepers suitable for use as a replacement for wood sleepers. The work continued the previous joint efforts of CSIRO and Rocla in developing pre-stressed geopolymer sleepers as a replacement for ordinary Portland cement sleepers. CSIRO had previously worked on developing a geopolymer formulation to meet the critical demands of a low-profile railway sleeper. Rocla provided the necessary specifications for the sleepers and made the pre-stressed sleepers from the new formulation.

Benchmarking the mechanical properties of a revised geopolymer mixture was provided by Rocla. Kaolite (clay) fly ash was used in a series of trials but the properties did not meet the target values – so the decision was made to revert to fly ash from the Bayswater power station in New South Wales. Mix optimisation using the Bayswater fly ash was completed however variations in the fly ash composition delivered inconsistent results – which did not meet the target material requirements for railway sleeper design specifications. An ongoing partnership between Rocla and CSIRO after the term of CSRP will re-evaluate the materials requirements for future railway sleeper production trials.

Thermal properties of geopolymers

Geopolymers are sufficiently durable and stable at high temperatures to be used in building fireproofing applications however using geopolymer fireproofing coatings on steel have not yet been exploited. This project developed fire-resistant geopolymer coatings that could potential be introduced into the market place.

The team developed a geopolymer composition that proved to be suitable for spray coating in terms of flow and spray-ability. To improve the fire-resistance performance of the mixture, a 10 weight percent (concentration) of vermiculite was added – a natural clay-like mineral that expands with the application of heat. Two size fractions were trialled, those below 63 microns and those over 63 microns. Adding vermiculite required extra water to maintain the spray-ability.

Several papers and a book chapter have been published based on this work.

Bayer residue geopolymers

Geopolymers with impressive physical properties have been successfully manufactured from Bayer residue at laboratory-scale. This new source material opens up opportunities for utilisation of significant amounts of industry by-product. Since the completion of major project work with Bayer residue based geopolymer, there has been an investigation into granulation of the material with international companies. Some experimental work was completed during 2008/09 and further work was then undertaken as part of CSRP project "Fundamentals of Bayer-based Geopolymer" (132).

Stream 3: Geopolymer Alliance

The Geopolymer Alliance aims to enhance the sustainability of the mining and power industries by promoting the uptake of geopolymer technology within existing industries such as the building and construction industry. The Alliance has been set up as a resource centre to provide support to industry and to ensure standards and regulations are available for alkali activated cements and concretes. In addition, the Alliance will conduct workshops and coordinate conferences to assist in promoting geopolymers.

The Foundation constitution and Alliance By-laws were finalised and approved by the CSRP Board. Geopolymer Foundation Ltd has been formally established to manage the Alliance. The first meeting of the Foundation's Board was held on 17 February 2010.

The Alliance prospectus was sent to potential members and now has 13 organisations as founding members. The inaugural meeting of the founding members was held in Perth on 4 May.

The Alliance is a member of RILEM (see www.rilem.net) and their Technical Committee on Alkali Activated Materials. This committee is charged with the responsibility of setting up European standards, test methods and codes of practice for AAM's (geopolymers). The most recent meeting was held in Jinan, China on 9 May.

The Alliance is also part of the Concrete Institute of Australia's committee set up to prepare a Current Practice Note on Geopolymer Concrete. This note is currently being drafted with considerable input from the Alliance and is expected to be published in December 2010. Following the recent resignation of the Chairperson, the Alliance's offer to chair the committee has been accepted. Dr Natalie Lloyd from Curtin University has been invited to join the committee and has agreed to write the chapter on Engineering Design Issues.

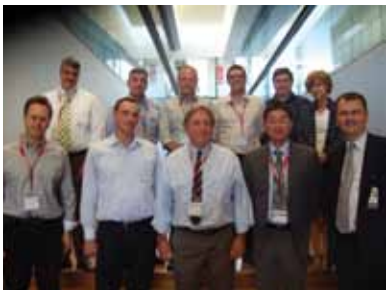
A symposium on geopolymer concrete was organised as part of the CIA's Concrete 09 conference. A full Geopolymer Alliance conference is planned for 2011/12.

For further information, refer to the Geopolymer Alliance website at www.geopolymers.com.au

The first meeting of the members of the Geopolymer Alliance.

Stream 4: Geopolymer sustainability metrics calculator

This project aimed to compare selected sustainable development metrics for geopolymer concretes with Portland cement concretes using a versatile reusable sustainability metric calculator. The Calculator clearly demonstrates that the source of alkali solutions and transport dominates the price, energy and carbon dioxide produced for geopolymer concrete.



The first meeting of the members of the Geopolymer Alliance.

Project Leader

Arie van Riessen (Curtin University)

Project Team

Alex Ciluzzo, Rob Hart, Barry Whittington, Min Xie, (Curtin University)

Industry Champion

Evan Jamieson (Alcoa)

Fundamentals of Bayer-based Geopolymers (132)

CSRP Participants, Curtin and Alcoa, have successfully produced a number of geopolymer samples using a combination of Bayer liquor and fly ash or silica fume as part of the "Geopolymer Concrete from Regional Waste Streams" (4B1) project. Since November 2007, the project has successfully converted the geopolymer paste to mortar by adding various sands. Also lime addition has been shown to enable the geopolymer to cure at ambient temperatures with a marked improvement in strength.

Results from all stages of the project have been extremely promising. However further fundamental research is required to measure the Bayer geopolymer aluminium and silicon bonding, to enable confirmation that the structure is in fact consistent with traditional aluminium-silicon inorganic polymers. This project aimed to better understand the Bayer liquor samples and enable an understanding of the influence of Bayer liquor impurities upon the geopolymer formation mechanism. Bayer geopolymer were compared and assessed to standard geopolymer formation and structure.

The project had two distinct paths, namely fundamental science and manufacture of geopolymer from Bayer liquor. The fundamental science work included x-ray diffraction (XRD), pair distribution function (PDF), and nuclear magnetic resonance analysis (NMR) of pure- and fly ash- based geopolymers. This research has provided an increased understanding of the formation and identification of geopolymers and is helping inform the applied research using industry residues. The XRD work made a breakthrough in the use of a calibration curve that enables the ratio of the precursor and geopolymer to be determined directly. A journal paper was written to report this development.

The applied work concentrated on developing consistent sample properties from different batches of liquor. Replacement materials for silica fume were also investigated, as well as different fly ashes so that silicon/aluminium ratios can be optimised. Production of geopolymer from 100 percent replacement of sodium hydroxide with Bayer liquor provided consistent and predictable results.

Further work on Bayer liquor geopolymer continues beyond the term of CSRP and will be funded by the industry sponsor.

Zero Waste and Minor Elements Program

Program Leader: Mr Warren Bruckard (CSIRO)

This program extended the work conducted under the foundation project "Toward Zero Waste", where a suite of Australian metallurgical waste products was obtained, characterised and processing/treatment opportunities identified. The three most prospective opportunities were associated with the treatment of bauxite residues, sulfide tailings and with discard zinc slags.

This program aimed to produce high quality product with minimal waste, with the ultimate outcome being "zero waste" flowsheets for minerals processing. Often a barrier to the beneficial use of waste streams is the minor elements embedded in materials which can pose a threat to our environment. Therefore, safe extraction and containment of these minor elements was a vital outcome of this program. In addition, early removal of these minor elements (which can contaminate the final product) will result in a higher quality product.

Smelters charge penalties for some minor elements in concentrates and these penalties reflect the adverse impact on the smelting process and the difficulty that the smelters have in treating the waste streams generated. As demand for metal grows and high grade, low impurity deposits are replaced by those with higher impurity levels, the impact of penalty elements is increasing. In some cases, smelter capacity is constrained by the ability to remove and dispose of the penalty elements.

The primary method for dealing with penalty elements in concentrates has been to blend concentrates to stay below the limits set for smelter feed. If a viable early removal option for penalty elements can be developed the economics of many ore bodies would improve and the environmental impacts reduced. Elements such as arsenic could be removed from metal concentrates at the concentrator, treated to recover valuables, stabilised, and stored in an environmentally safe way.

Program Highlights

- Flowsheet developed for dealing with arsenic-bearing base metal sulphides was developed and tested at small scale in the laboratory – used in a spin-off project to further demonstrate feasibility at bench scale.
- Quantitative mineralogical data results suggest that grinding the rougher pulp concentrate may be sufficient to enable some separation of the arsenic-bearing sulfides.
- Promising results and strong collaborations will ensure work continues beyond the term of CSRP.

Early Flotation of Mineral Components Containing Arsenic (AMIRA P970) (2D9)

CSRP funded the "Early Removal and Safe Disposal of Arsenic and Other Minor Elements during Base Metal Processing" (2D8) project in 2007/08 to develop new flowsheets for dealing with minor and toxic elements in the processing of base metal sulphides. In that project, a new flowsheet for dealing with arsenic-bearing base metal sulphides was developed and tested at small scale in the laboratory.

Arsenic was removed at the flotation stage of beneficiation so that a "clean", low-penalty element concentrate could go forward to smelting. The penalty element rich co-concentrate would then be treated by selective roasting to partition the penalty elements into a low volume stream and to recover valuables in a separate stream. The unwanted material would be chemically and physically stabilised such that it could be safely and economically stored. The work from project 2D8 was then carried forward into this follow-on project (2D9 / AMIRA P970). This new project was established to further demonstrate at bench scale the technical feasibility of the early removal of arsenic by selective flotation, particularly of arsenic-bearing copper ores provided by sponsors – Anglo American and Rio Tinto. This project officially commenced in late May 2009 and is scheduled to run for two years. In 2009/10 both sponsors provided ore samples for the study.

The potential difference of a mineral-solution interface, which is indicated by pulp potential, has been shown to be closely related to the floatabilities of sulphide minerals. An initial set of pulp potential tests on the Rio Tinto ore indicated that there may be only a limited opportunity to produce a separation. Further tests are required to confirm what level of separation may be possible. Further work is also required on the ore to investigate whether chemical or physical changes to the test conditions provide a better separation opportunity.

For the Anglo ore, copper recoveries for the preliminary benchmark floats are lower than expected and further work may be needed to increase this before the initial pulp potential tests. Quantitative mineralogical data results (QEMSCAN) suggest that grinding the rougher pulp concentrate may be sufficient to enable some separation of the arsenic-bearing sulfides. While the major copper mineral in both ore samples is chalcopyrite, there would appear to be enough difference in the sulfide mineralogy for the project to benefit from testing on both ores. This project is entering its second year and continues beyond the term of CSRP with the support of AMIRA.

Project Leader

Warren Bruckard (CSIRO)

Project Team

Kevin Davey, Cathy Edwards, Sharif Jahanshahi, Mark Ma (CSIRO)

Industry Champion

Gray Bailey (AMIRA)

Research Portfolio

As 2009/10 was the final year of CSRP's funding, the majority of projects were completed prior to 30 June 2010. The following is a list of all projects (by program) completed during the term of CSRP.

Sustainable Development Program

BP Industrial Synergies Opportunities Investigation (3B6)
Capturing Potential Sustainability Improvements of CSRP Research Project Outcomes (1A3)
Capturing Regional Synergies in Kwinana Industrial Area (3B1 Extension) *
Detailed Scoping Study into Evaporative Water Supply/Treatment System in the Kwinana Industrial Area (125) *
Detailed Scoping Study into Potential Effluent Synergies in the Kwinana Industrial Area (126) *
Developing Local Synergies in the Gladstone Industrial Area (3C1 Extension)
East Rockingham Wastewater Treatment Plant – Industrial Synergies Scoping Study (131) *
Enabling Tools and Technologies for Capturing Regional and Supply Chain Synergies (3A1)
Energy Issues Paper (1A2)
Kwinana Industrial Inorganic By-product Reuse (3B3)
Minerals, Metals and Sustainability: A Textbook for the Future (124) **
Regional Synergies in the Rustenberg Area (AMIRA P913) (3D1)
Review of Cost Effective Systems to Minimise Water Losses by Evaporation from Mine Site Process Water Storages (AMIRA P881) (2C1)
SRP Frameworks and Metrics (1B1)
Sustainability and Eco-Efficiency Assessments at Operating Plants (2A2)
Sustainable Development Program Extension (101) *
Water Auditing for Improved Water Management in the Resource Processing Industries (106) *
Water Issues Paper (1A1)

Energy Efficient Liberation and Comminution Program

Characterisation of Rock Mass for Liberation at Coarse Sizes (2B8) *
Comminution Program (AMIRA P9O) (2B2 Extension) **
Comminution Program Research (AMIRA P9N) (2B2)
CSRP Comminution Program Leadership (67) *
Demonstration of Banana Screen Modelling Capabilities (2B11) *
Development of a Non Invasive Continuous Mill Charge Monitoring System (2B6)
Energy Efficient Liberation and Comminution (2B1 Extension) *
Flotation of Coarse Particles (110) *
HPGR Comminution Classification Circuits (AMIRA P929) (2B5)
HPGR Triple Pass Circuit Concept (2B10) *
Improvement of Energy Efficiency of Rock Comminution through Reduction of Thermal Losses (2B7)
Reduced Erosion in Multiphase Flow Equipment (AMIRA P931) (2B9)
Rotary Kiln Technology (AMIRA P5831A) (2B3)
SAG Mill Monitoring Using Surface Vibrations (AMIRA P667A) (2B4)

CO2 Breakthrough in Metal Production Program

Biomass 1A: Mallee Leaf/Twig Charcoal as Metallurgical Reductant (WA) (4C2)
Biomass 2: The Utilisation of Carbonaceous Waste in Metallurgical Processes (4C3)
Biomass as a Reductant in Modern Smelting Processes (4C1)
Biomass in the Iron and Steel Industry (4C4)
Dry Processing of Minerals (AMIRA P902) (2C2)
Heat Recovery from Molten Slags through Dry Granulation (4D2)
Slag Waste Heat Recovery and Utilisation (4D1)
Utilisation of Carbonaceous Waste in Tasmanian Metallurgical Industries (4C5)

Bauxite Residue Program

Alternative Lime Source Trials (4A4) *
Assessing the Potential for Hyperspectral Technology to Verify the Distribution of Red Mud used as a Soil Amendment in Agriculture (4A9)
Bauxite Residue Sustainability Measure of Improvement (1B2)
Characterisation of Radioactivity in Bauxite Residues (2D2)
Demonstration of Infiltration Barrier Utilising Bauxite Residue (130) **
Demonstration Trial for ReSand® (129) *
Long Term Monitoring of the Impacts of (Alkaloam) Bauxite Residue Application to the Peel Harvey Coastal Plain Catchment (4A3)
Long Term Monitoring of the Impacts of (Alkaloam) Bauxite Residue Application to the Peel Harvey Coastal Plain Catchment – Sustainability and Risk Review (4A3 Extension 1) **
Magnetic Separation of Alcoa Sands (3B2)
Minerals Separation from Bauxite Residues (4A2)
Monitoring of Red Sand ™ used in Greenlands Road Upgrade (128) **
ReSand® Investigation for Greenlands Road Upgrade (127)
ReSand® Production to Specification (3B4)
Use of Beneficiated Residue Sands (4A7)

Geopolymer Program

Fundamentals of Bayer-based Geopolymers (132) *
Geopolymer Concrete from Regional Waste Streams (4B1)
Geopolymer Concrete from Regional Waste Streams (4B1 Extension) *
Geopolymers in Mine Fill at Mt Isa Mines (4B2)

Zero Waste and Minor Elements Program

Control of Minor Elements (2D1)
Early Removal and Safe Disposal of Arsenic and Other Minor Elements during Base Metal Processing (2D8)
Early Removal of Arsenic Mineral Components (AMIRA P970) (2D9) **
Minor Elements in Smelting (AMIRA P671) (2D6)
Toward Zero Waste (4A1 Extension)

Education and Training Program

Developing Sustainable Attitudes: Teacher Personal Development (5B1)
Gladstone Area Mathematics, Science and Engineering Teachers (GAMSET) Enhancement Program (5B3)
Motivational Factors Driving Career Choices in the Minerals Sector (5B2)
Sustainability Training Pilot (5A1)

* Project was completed in the 2009/10 reporting period.
** Project continued beyond the term of CSRP (30 June 2010), as per arrangements with project participants.

Collaborations

Collaboration in CSRP is considered integral to success at a researcher-researcher and industry-researcher level. There are many ways in which CSRP involves its participants to ensure that a collaborative environment is maintained. Strategies that have been in place since the inception of CSRP, and have been an integral part of collaborations between our participants and external clients include:

- A multidisciplinary approach to all projects facilitated through a Technical Advisory Panel consisting of industry and research representatives.
- An active Technical Advisory Panel Working Group constantly reviews projects.
- For every project, there is an Industry Champion who is able to provide input into the project development.
- Working with industry groups such as AMIRA, Minerals Council of Australia, Kwinana Industry Council, Gladstone Area Industry Network and the Australasian Institute of Mining and Metallurgy provided opportunities to collaborate with external organisations.

The inclusion of both industry and academia allows potential new research and industry collaborations to be brought to the fore and ensures world class research while remaining relevant to industry.

Collaborative activities have continued with participants and external organisations. Some notable examples are given here.

Integrating sustainability

CSRP undertook two case studies with its participants to examine the sustainability opportunities of proposed improvements to existing mine operations and potential new mine sites. The case studies applied CSRP's SUSOP® (SUStainable OPerations) mechanism for identifying sustainability opportunities and evaluating the sustainability benefits and impacts of the proposed options.

The SUSOP® mechanism is a new and practical approach for incorporating sustainable development principles into the design and operation of industrial processing plants. SUSOP® assists companies in linking performance imperatives to sustainability objectives by facilitating a structured, methodical, process to identify and implement ways to use less water and energy, generate lower greenhouse gas emissions and minimise waste volume and toxicity.

Led by the Sustainable Minerals Institute at the University of Queensland, the CSRP research and development team includes industry participants, Hatch and GHD, and other research providers, University of Technology Sydney, CSIRO, University of Newcastle and Curtin University of Technology.

Through these case studies, CSRP helped deliver innovative sustainability opportunities for its participants and further progressed the development of SUSOP®. The aim is for SUSOP® to be a sustainable development analogy to the way in which safety has been rigorously and systematically incorporated into industrial operations.

Greening Australia's roads

CSRP worked with the Department of Agriculture and Food WA, Main Roads WA, Southern Gateway Alliance, Alcoa, Wallis Water and other project partners to establish two demonstration trials associated with the new Perth Bunbury Highway in Western Australia. In the first trial, more than 2500 cubic metres of ReSand® was extracted from bauxite residue and used as road base to widen the Greenlands Road access to the new highway near Pinjarra. In the second trial, a demonstration "nutrient trap" utilising bauxite residue was installed by the side of the new road. The trap collects water run-off and removes nutrients such as phosphates and nitrates, to help prevent algal blooms in the surrounding waterways.

In these instances, the recovery of useful by-products from mineral residues has a range of potential benefits including:

- replacement of increasingly scarce supplies of quarry sand;
- reduction in the clearing of natural bushland for sand quarries; and
- reduction in the demand for expensive waste residue containment facilities.

These benefits can lead to reduced costs, less energy and water use and lower greenhouse gas emissions.

Geopolymer burial crypts

CSRP participants teamed with Austeng (a special purpose engineering company based in regional Victoria) to combine two novel technologies in a multi-million dollar demonstration project to the advantage of a wide range of stakeholders. By using technical knowhow in geopolymer concrete with Austeng's Modern Burial System technology, the following outcomes are achieved:

- 80 percent less greenhouse gas emissions from concrete manufacturing
- 30 percent increased utilisation of scarce cemetery land
- Reduced power station waste to landfill
- Reduced need for land clearing for lime quarries
- Reduced energy consumption in cement kilns

Cemeteries are a fact of life and whilst it is not something that we generally think about, the impact of expanding cemeteries is significant. Often there simply isn't enough land to expand, or the land that is available is too rocky, too sandy, has a high water table or is otherwise unsuitable. In 1996, the Rockhampton City Council Parks Department designed a new Modern Burial System of interlocking precast concrete crypts to overcome these dilemmas.

However, production of conventional concrete contributes an estimated two billion tonnes per year of global carbon dioxide emissions. That's 8 percent of the world's GHG emissions or equivalent to 450 million cars! Since 2003, CSRP has been developing technologies and expertise in geopolymer concrete – which generates 80 percent less greenhouse gas emissions than conventional concrete and produces a more durable, stronger, acid resistant and fire resistant concrete.

Another major advantage of geopolymer concrete is that it can be made using "waste" feed stocks such as fly ash (from coal-fired power stations), mine tailings and bauxite (alumina) residues. Millions of tonnes each year of these potential feed stocks are currently being disposed of in large and costly containment facilities rather than being diverted to beneficial uses, such as geopolymers.

By combining geopolymer technology with the, CSRP and Austeng aimed to provide a truly green solution – reducing costs, energy use, water use, land clearance and greenhouse gas emissions in the process. Geopolymer concrete is certainly a building product for the low greenhouse gas emission future.

This innovative project will be carried out beyond the term of CSRP through an ongoing collaboration between Rocla and Austeng.

New positron emission particle tracking lab in South Africa

The world's second Positron Emission Particle Tracking (PEPT) facility in Cape Town, South Africa was officially opened on 4 August 2009 with a welcoming address, a tour of the facilities and an informal dinner.

PEPT is based on the tracking of a single tracer particle which has been labelled with a radionuclide that decays via beta-plus decay, within the field of view of a modified PET camera. This provides the basis for a technique for the characterisation and visualisation of particulate flow within aggressive industrial environments, such as tumbling mills, flotation cells and powder mixers.

The new laboratory is situated at iThemba LABS (national cyclotron centre) and funding was provided in-part by

CSRP along with other international collaborators, including the National Research Foundation of South Africa, Imperial College London, and the University of Cape Town through its Centre for Minerals Research, the Minerals to Metals Initiative, and the Equipment Committee.

Visit www.pept.uct.ac.za for more information on the PEPT facility.

Clockwise from top: Prof Malcolm Powell beside the iThemba cyclotron; Dr Indresan Govender (University of Cape Town) at the PEPT opening; Prof Malcolm Powell, Dr Indresan Govender and Dr Aubrey Mainza (University of Cape Town) with the inside of the PEPT camera. © UCT and M. Powell

Commercialisation and Utilisation

Commercialisation Manager: Dr Mark Neville

Commercialisation and utilisation of research within CSRP is governed by a Commercialisation and Utilisation Plan (CUP), which was designed specifically to ensure that all commercialisation mechanisms (sale, licence, joint venture, strategic alliance, spin-off etc) were available to CSRP for the development and uptake of its outputs. It also provided the overall system and framework for analysis of commercialisation options. Broadly speaking, the value from any Intellectual Property (IP) created by CSRP will be realised by uptake/adoption by CSRP sponsors/industry organisations, non-CSRP sponsors/industry organisations in Australia, and commercialisation of IP through a commercial venture.

While this is a top down approach, CSRP also had the option to initiate CUPs at the project level. In general, IP was identified, protected and managed at the level of an individual IP asset, and the CUP provided for this with the staged development of an "IP asset" CUP.

Intellectual Property

As reported elsewhere in this annual report, plans have been developed to allow further utilisation and commercialisation of the following outputs:

Dry Slag Granulation – Allows the iron and steel industry to improve its water- and energy-efficiency through recovering and utilising wasted heat and improving current processes.

Geopolymer Alliance/Foundation – Established to enhance the sustainability of the construction, mining and power industries by promoting and championing the uptake of geopolymer technology. For more information refer to www.geopolymers.com.au

JK Rotary Breakage Tester – An innovative device that addresses the need for rapid breakage characterisation of ore is helping to optimise the design of grinding circuits. Improvements include significant reduction in energy consumption and associated greenhouse gas emissions, reduced mechanical wear, reduced water consumption and greater production.

Geopolymer products – Concrete that generates 80 percent less greenhouse gas emissions than conventional concrete. Geopolymers produce a more durable, stronger, acid resistant and fire resistant concrete – resulting in concrete products with longer service lives (e.g. sewer pipes and railway sleepers).

SUSOP® – A developing management tool for incorporating sustainability principles into plant design and operation and addressing the need of end-users for a recognised technique to integrate sustainability into business outcomes.

ReSand® – A Sand CIP assignment and commercialisation deed was established between Alcoa, SRP Management Ltd and SRP Intellectual Property Ltd in January 2010. This agreement allows Alcoa to use CSRP's ReSand® intellectual property in the commercialisation of their Red Sand – enabling Alcoa to promote their sand as a more sustainable source of construction sand.

The wind-up deed has identified and assigned all Centre IP, with the overriding aim to maximise the uptake of and benefits derived from CSRP's outputs.

For more detailed information on the outputs from CSRP, please read our "highlights" document published in October 2010, and available on our website at www.csrp.com.au/publications/

End-user Involvement

CSRP's industry participants are all actively involved in one or more of our research projects, with increasing involvement in plant trials and demonstration projects. The tables below outline our industry and research participants during 2009/10 and their activities within CSRP:

CSRP Core Participant	Activities
Alcoa	Interest in all outcomes and technologies developed within CSRP. Specific projects on bauxite residue characterisation, stabilisation and alternative uses. Involvement in the Education and Training Program.
ANSTO	Interest in all outcomes and technologies developed within CSRP. Specific projects in the Geopolymer Program.
BHP Billiton	Interest in all outcomes and technologies developed within CSRP. Specific project on energy-efficient liberation and comminution. Member of the Kwinana Industries Council.
Curtin University	Interest in excellence in cleaner production, regional synergies and all outcomes and technologies developed within CSRP.
CSIRO	Interest in all aspects of mineral processing, computational modelling, advanced materials, and life cycle analysis.
Newmont	Interest in all outcomes and technologies developed within CSRP. Specific projects on energy-efficient liberation and comminution and technologies to reduce water evaporation. Involvement in the Education and Training Program.
Rio Tinto	Interest in all outcomes and technologies developed within CSRP. Specific projects on energy-efficient liberation, comminution, and biomass as fuel and reductant in modern smelting processes.
University of Queensland	All aspects of sustainable development in the resource sector through the Sustainable Minerals Institute. Specific interest in comminution, water management and social responsibility.
Xstrata	Interest in all outcomes and technologies developed within CSRP. Specific projects on energy-efficient liberation and comminution.

CSRP Supporting Participant	Activities
Anglo Platinum	Specific interest in energy-efficient liberation and comminution, and regional synergies projects in South Africa.
BlueScope Steel	Specific projects on biomass as a fuel and reductant and dry granulation of molten slags.
GHD	Interest in greenhouse gas management, renewable energy, energy efficiency, eco-efficiency, cleaner production, industrial ecology, regional synergies, corporate sustainability, life cycle assessment, eco-design, and green chemistry and engineering.
Murdoch University	Specific projects on water auditing in the minerals industry. Involvement in the Education and Training Program.
OneSteel	Specific projects on the review of technologies to reduce water evaporation, biomass and dry granulation.
Orica	Specific projects on sustainability and eco-efficiency opportunity assessments at operating plants and geopolymer concrete from regional waste streams.
Rocla	Specific project on geopolymer concrete from regional waste streams.
University of Newcastle	Specific projects on flotation of large particles for coarse liberation of minerals and sustainable resource processing.

CSRP Associate	Activities
Australian Government Department of Environment, Water, Heritage and the Arts	Interest in all outcomes and technologies developed within CSRP.
Hatch	Interest in all outcomes and technologies developed within CSRP. Specific projects on site-based eco-efficiency reviews and energy-efficient liberation and comminution.
Kwinana Industries Council	Enabling tools and technologies for capturing regional synergies (particularly in the Kwinana industrial area).
Minerals Council of Australia	Interest in all outcomes and technologies developed within CSRP.
URS	Interest in all outcomes and technologies developed within CSRP. Specific project on the review of technologies to reduce water evaporation, and sustainability assessment of bauxite residue.

CSRP is a truly collaborative organisation where research partners are not limited to participants, thus ensuring the best outcome for the research projects. More than thirty non-participant organisations are involved as project affiliates with many CSRP projects. This greatly enhances CSRP's direct contact with end-users of our technologies. The following table lists our project affiliates for 2009/10, as well as our external research collaborators:

Project	Project Affiliate (non-CSRP participants)
Alternative Lime Source Trials (4A4)	Department of Agriculture and Food WA
Capturing Regional Synergies in Kwinana Industrial Area (3B1 Extension)	Kwinana Industries Council members (e.g. BP, Cockburn Cement, HIsmelt, Nickel West, Tiwest, Verve Energy, Water Corporation)
Comminution Program Research (AMIRA P9O) (2B2)	AMIRA International P9O project sponsors and research providers: Hacettepe University, McGill University, Universidade Federal do Rio de Janeiro, University of Cape Town, AngloGold Ashanti Ltd, Ausenco Ltd, Barrick Gold Corporation, Bateman Minerals & Metals Pty Ltd, Cayeli Bakir Isletmeleri-INMET, Companhia Vale do Rio Doce, COREM, FLSmidth Minerals, Freeport-McMoRan Mining Company, Impala Platinum Ltd, Intellection Pty Ltd, LKAB, Lonmin Platinum, Magotteaux Pty Ltd, Metso Minerals Process Technology, Newcrest Mining Ltd, Outotec, Outotec Minerals OY, OZ Minerals, Polysius AG, Russell Mineral Equipment, Senmin South Africa Pty Ltd, Servicios Industriales Penoles SA de CV, Teck Metals Ltd, Zinifex Port Pirie
CSRP Comminution Program Leadership (67)	University of Cape Town, University of Erlangen
Demonstration of Infiltration Barrier Utilising Bauxite Residue (130)	Conservation Council of WA, Department of Agriculture and Food WA, Main Roads WA, Southern Gateway Alliance, Wallis Group
Demonstration Trial for ReSand® (129)	Main Roads WA, WML Consultants
Detailed Scoping Study into Evaporative Water Supply/ Treatment System in the Kwinana Industrial Area (125)	Kwinana Industries Council members (e.g. BP, Cockburn Cement, CSBP, HIsmelt, IPM Operation & Maintenance Kwinana, Nickel West, Tiwest, Water Corporation, Wesfarmers LPG)
Detailed Scoping Study into Potential Effluent Synergies in the Kwinana Industrial Area (126)	Kwinana Industries Council members (e.g. BP, Cockburn Cement, CSBP, HIsmelt, IPM Operation & Maintenance Kwinana, Nickel West, Tiwest, Water Corporation, Wesfarmers LPG)
Early Flotation of Mineral Components Containing Arsenic (AMIRA P970) (2D9)	AMIRA International P97O project sponsors and research providers: Anglo American Chile Ltda

East Rockingham Wastewater Treatment Plant – Industrial Synergies Scoping Study (131)	Department of State Development WA, LandCorp, Water Corporation WA
Energy Efficient Liberation and Comminution (2B1 Extension)	iThemba Labs, University of Cape Town, University of Erlangen
Geopolymer Concrete from Regional Waste Streams (4B1 Extension)	Geopolymer Alliance members (e.g. Ash Development Association of Australia, Australasian Slag Association, Blue Circle Southern Cement, Cement Australia, Independent Flyash Brokers, Parsons Brinckerhoff Australia, University of Melbourne, University of Southern Queensland)
HPGR Triple Pass Circuit Concept (2B10)	AMMTEC Ltd
Long Term Monitoring of the Impacts of Bauxite Residue Application to the Peel-Harvey Coastal Plain Catchment – Sustainability and Risk Review (4A3 Ext 1)	Department of Agriculture and Food WA
Monitoring of Red Sand ™ used in Greenlands Road Upgrade (128)	Department of Agriculture and Food WA
Sustainable Development Program Extension (101)	University of Technology Sydney
Water Auditing for Improved Water Management in the Resource Processing Industries (106)	BP, CSBP

Communication

Communications Officer: Ms Lisa Laurie

The Communications Strategy has ensured that the minerals processing industry and the wider general community has access to information about CSRP and our activities and achievements. To meet the aims of the Communications Strategy, there was also a need for internal communication to ensure CSRP members were aware of all the various activities being undertaken.

Promoting our successes

Promoting successes will ultimately enhance the reputation of CSRP and its research outcomes. It also provides an avenue whereby there is tangible evidence that the objectives of CSRP are being met. It is equally important to promote these successes to the minerals processing industry and the wider community. **Promotion** is generally through the external newsletter and other media and publicity mediums.

The external newsletter is issued 2-3 times per year and covers issues of interest to stakeholders, such as updates on our research, demonstrations projects and pilot plants; upcoming professional development courses; "meet and greet" of CSRP staff; and student projects and graduates.

External **conferences, workshops and presentations** provide an excellent opportunity to **network** with other researchers and industry personnel. Well targeted public presentations, such as plenary sessions at conferences, all contribute to raising the public awareness of CSRP and the role it plays in the mineral processing industry and the wider community.

CSRP members were **personally invited** to present at the 12th European Symposium on Comminution and Classification Conference (Finland), the Minerals Processing Conference 2010 (South Africa), and the TechNet 2009 conference (Perth).

Members of the CSRP community also attended and presented at more than 15 international conferences:

- Comminution '10, Cape Town, South Africa
- XXV International Mineral Processing Congress (IMPC 2010), Brisbane
- International Topical Meeting on Nuclear Research Applications and Utilisation of Accelerators, Vienna, Austria
- Goldfields Environmental Management Group Workshop (GEMG) 2010, Kalgoorlie
- Sustainable Development Indicators for the Minerals Industry (SDIMI) 2009 Conference, Gold Coast
- Water in Mining 2009 Conference, Perth
- 7th International Conference on Computational Fluid Dynamics in the Minerals and Processing Industries (CFD 2009), Melbourne
- 5th International Conference on Discrete Element Methods (DEM5 2010), London, UK
- 24th Biennial Conference of the Concrete Institute of Australia (Concrete Solutions 09), Sydney
- Sustainable Mining 2010 Conference, Kalgoorlie
- 2nd International Congress on Green Process Engineering (GPE 2009), Venice, Italy
- 8th World Congress of Chemical Engineering (WCCE8), Montreal, Canada
- 41st Annual Canadian Mineral Processors Conference (CMP 2009), Ottawa, Canada
- 2009 Society for Sustainability and Environmental Engineering International Conference (SSEE), Melbourne
- Mineral Processing Plant Design 2009 Conference, Tucson, Arizona
- 10th Mill Operators Conference 2009, Adelaide
- Extraction and Processing Division (EPD) Congress 2010, Seattle, USA
- 7th International Conference on Computational Fluid Dynamics in the Minerals and Processing Industries (CFD 2009), Melbourne
- 4th Asian Particle Technology Symposium (APT 2009), New Delhi, India

The **Sustainable Development Indicators for the Minerals Industry (SDIMI) conference** was held on 6-8 July on the Gold Coast and was chaired by our Sustainable Development Program Leader, Prof David Brereton, from the University of Queensland. The event was a huge success, with over 160 delegates attending from over 12 different countries including Canada, South Africa, Germany and Australia.

Presentations were varied and covered topics such as sustainability reporting, human development in mining zones, sustainable futures, optimising mine site design, sustainability roadmaps, social conflict and mining, policy development, remote sensing, and life cycle assessments. Various CSRP staff members chaired sessions – including Stevan Green, Dan Churach, Glen Corder (University of Queensland), Philip Bangerter (Hatch), Sharif Jahanshahi (CSIRO) and Andrew Murphy (Hatch).

Stevan Green chaired the CSRP-run Sustainability Assessment Forum. The objectives of the forum were to present actual case studies on implementing sustainability initiatives, discuss the learnings from these case studies and elicit potentially feasible methods for putting sustainability initiatives into practice.

To "plant the seeds" for discussion, a panel of four sustainability practitioners delivered specific examples of sustainability initiatives (successful or otherwise) or vital characteristics, drawing on their experience, needed to drive sustainability initiatives to practical outcomes in the minerals industry. The panel comprised:

- Malcolm Powell – Professorial Chair in Sustainable Comminution at the University of Queensland
- Patrick Crittenden – Principal Sustainability and Climate Change for GHD
- Rick Humphries – Director, Carbon for Greening Australia
- Adrian Abbott – Queensland Regional Manager for Energetics

Important messages emerged from each presentation – not all on the same theme as the backgrounds of the panel were distinctly different. These messages from the panellists highlighted:

- Perceived risk and technical change can be a critical barrier for new initiatives, even when there are potentially sizeable sustainability and cost benefits;
- A collaborative "whole of business" approach is necessary even when tackling problems that appear to be solely in the technical domain;
- The overwhelming requirement that successful sustainability initiatives need is a "business case" to demonstrate value and a champion at the highest level in an organisation; and
- Improved sustainability performance at site level needs to be established quantitatively through systematic and transparent data monitoring and analysis.

The outcomes from this Forum have been used to further develop the SUSOP® mechanism. Together with the other new and innovative ideas that emerged from the conference, these outcomes will form the basis for an action agenda which to be re-visited by delegates at the next SDIMI conference in 2011.

A CSRP **media release** entitled *"Greening Australia's roads"* (21 September 2009) was published by the Academy of Technological Sciences and Engineering "Focus" magazine, the Australian Nanotechnology Alliance and

Future Materials "NanoVate" newsletter, South Western Times newspaper, Eco Investor magazine, and the Department of Innovation "CRCs Success Through Innovation" newsletter. The article was also published online by Minerals Processing (Reed Business Information), Mandurah Mail, MEI Online, Drive Odd Spot, and the Community Newspaper Group.

CSRP's **website** www.csrp.com.au is an important promotional and information distribution tool. Project information, publications, newsletters, conference information, staff and education information have been updated as soon as possible after the receipt of the required details.

Stevan Green presenting during the Sustainability Assessment Forum at SDIMI 2009.

Final showcase

CSRP hosted its **final conference** for its participants and industry affiliates during February 2010. To maximise the use of precious time and resources, the conference was divided into two one-day sessions – one in Brisbane on 16 February and the other the following week in Perth on 23 February. The presentations at each location were similar however in Brisbane the emphasis was on sustainable development and minerals processing, and in Perth the emphasis was on by-product utilisation and geopolymers.

With an underlying theme of "***looking back, looking forward***", the dual location format was designed to open the dialogue and allow better engagement between researchers and industry on potential collaborations.

Each full-day session was chaired by CEO, Stevan Green, and began with an overview of CSRP's achievements and highlights from the past six years. CSRP program leaders then presented specific highlights from their areas of work, which led into discussions for advancing the R&D outputs and plans for going forward.

Amidst bouts of heavy Brisbane rainfall, the audience of fifty listened to program leaders from the University of Queensland. Dr Glen Corder (Centre for Social Responsibility in Mining) presented on the evolution of sustainable development research within CSRP, tools and metrics, regional synergies and the SUSOP® mechanism. Prof Malcolm Powell (JKMRC) then presented CSRP's research on improving the energy efficiency of crushing and grinding (comminution) circuits – including coarse particle liberation, high pressure grinding rolls, computer modelling and simulation, mill liner design, abrasion, and ore breakage tests.

In Perth where the weather was dryer and warmer, yet another fifty attendees listened to program leaders from Curtin University of Technology and Alcoa World Alumina. Prof Arie van Riessen (Curtin) presented work from the Geopolymer Program including alternative cementitious materials, utilisation of industry residue, paths, railway sleepers, sewer pipes, acid resistance, fire resistance, mine backfill, evaluation of geopolymer formulations, sustainability and cost metrics, and the Geopolymer Alliance.

Dr Evan Jamieson (Alcoa) then presented on the Bauxite Residue Program including physical separation processes, using ReSand® (coarse sand fraction) for road construction trials, broad acreage use of Alkaloam® (finer fractions) to improve acid soils, roadside nutrient stripping filters, soil amendments, community understanding and perceptions, and using bauxite residue as a feedstock for geopolymers.

CSRP thanks all those who participated for making the final conference a great success.

Communicating with participants

Internal communication has been an important asset to CSRP to ensure that all members are aware of the activities occurring within CSRP as well as engendering a sense of belonging. Information ranges from general administration information through to project information and updates. The exchange of information is a core component of a collaborative research organisation. Given that the locations of research groups are spread across Australia, this exchange can take many forms.

The Executive and Technical Advisory Panel Working Group (TAPWG) meet fortnightly via **teleconference** to discuss higher level administrative matters and individual program issues. This form of communicating has proven to be a valuable and efficient method of regular communication with Program Leaders.

The Executive and TAPWG also meet **face to face** each quarter to probe further into any issues that have arisen and to address strategies and issues. Face to face meetings are also important for project teams. For multi-institutional projects, face to face meetings provide an opportunity for the research effort within the project to be more cohesive and directed. These are organised by the project leader and team members as appropriate – however, on occasion, the CEO may encourage such meetings to take place more frequently.

Internal communication is also facilitated by the monthly **newsletter**, which is sent to all members of CSRP. The newsletters keep members up-to-date with information ranging from general information from CSRP headquarters, new staff appointments, up coming events, new publications and generic project information. Contributions to this newsletter generally come from the Executive, however other members are encouraged to supply information they wish to be disseminated.

Quarterly Project Reports provide a summary of results achieved through the proceeding quarter and allow a snapshot view of the overall progress of the project. A summary report of all projects is collated and disseminated to the appropriate people. The CEO and Business Manager use the full report to track the progress of all aspects of projects while the summary is used to update industry participants, the Governing Board, the TAPWG and other members of CSRP.

Publications

CSRP's publications include conference papers, journal articles, project reports, presentations, workshops, book chapters and media articles. The number and quality of these publications forms part of our objectives and is a specific performance measure. For this reason, it has been important to CSRP to keep an up-to-date list of publications. Project reports also form part of our intellectual property. A complete list of our publications can be found on our website at www.csrp.com.au/publications and publications for 2009/10 appear at the end of this annual report.

Education and Training

Education Manager: Dr Dan Churach

The Education Program is based on the premise that the key to any sustainable enterprise is people – and that the nurturing of the next generation of scientists, engineers and site personnel can only be accomplished with an input of bright, well-educated students interested in applying scientific principles to solve sustainability problems facing industry. The Education Program aimed to influence graduates who were not only outstanding scientists and engineers, but also were grounded in a strong belief that economic growth and environmental sustainability are quite compatible within the mineral resource sector.

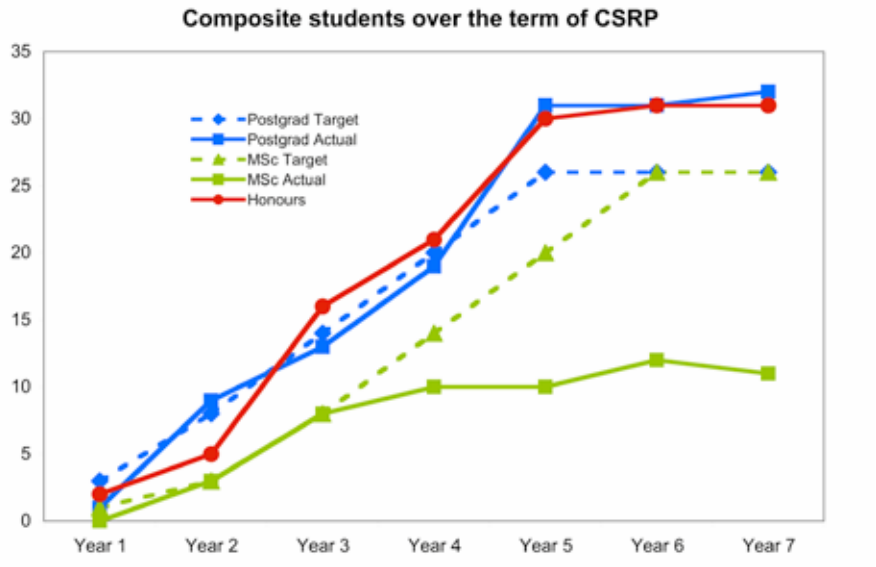
The 2009/10 year was a productive one for the Education Program. As Australia and the world adjusted to and overcame the global financial crisis, a variety of stresses came to bear on tertiary education within the mineral resource processing disciplines. As industry began to bounce back from plant closings and abandoned projects, several CSRP students were lured away from study and back into the mineral resource sector. In spite of the tumultuous economy, CSRP was able to meet or exceed our student targets and continue our outreach to school teachers, students and the public.

Program Highlights

- Total postgraduate population of 32 PhD, 11 Masters, 31 Honours and 38 undergraduate students.
- Continued collaboration with the Minerals Tertiary Education Council's "Metallurgical Education Partnership" that is delivering a definitive course in metallurgical process design for final year students at three Australian universities.
- Over 100 additional school teachers participating in professional development activities across Australia.
- Community outreach activities continued – helping to address the shortage of young people choosing careers in the mining, minerals and resource processing industries in Australia.

Postgraduates

At the end of June 2010, the total postgraduate population (active and completed) was 43 PhD and Masters. Of this total, 23 students were pursuing PhDs and nine had completed their doctorates. The number of master degree students enrolled or completed was 11, against the target level of 26. The total number of doctoral students over the term of CSRP superseded the target (31 as opposed to 26 anticipated) compensating for the shortfall in masters degrees. Additionally, CSRP funded 31 successful Honours student projects and 38 undergraduate student projects – fostering a wide based student interest in basic research aimed at a more sustainable mineral resource industry. In all cases of students supported by the Education Program, research projects contributed to the overall objectives and work of CSRP.



Undergraduates

CSRP has supported a variety of undergraduate initiatives since its inception. Undergraduate projects are funded both to support ongoing research and to offer insight and encouragement to students to consider careers in research. In some cases, participant university structures allow a number of these undergraduates (e.g. fourth year projects) to earn an Honours degree upon exemplary completion of their thesis. During the 2009/10 year, these types of projects were carried out at Curtin University, Murdoch University and the University of Queensland. In nearly all cases, industry supervision complemented academic supervisors.

Minerals Tertiary Education Council

CSRP has collaborated with the Metallurgical Education Partnership – an initiative of the Minerals Tertiary Education Council (MTEC) and funded by the Minerals Council of Australia. The initial goal of this collaboration was the development and delivery of a definitive course in metallurgical process design for final year students in the three universities which provide metallurgical/minerals engineering degree programs in Australia – namely Curtin University (Western Australia School of Mines), Murdoch University and the University of Queensland.

The course is designed to include maximum input from industry experts and aims at addressing sustainable processing issues in the early stages of a design project. Dr Nimal Subasinghe (Curtin University), Dr Aleks Nikoloski (Murdoch University), Philip Bangerter (Hatch) and Glen Corder (University of Queensland) have all been contributors to the design and implementation of this program. The final presentations for the 2009 Process Design Project were held via videoconference on 10 November. Teams of fourth year metallurgy students from the three member universities presented their work to each other and invited guests.

Stevan Green presented "Sustainability – Big Picture" on 30 July 2010 to a joint session of extractive metallurgy fourth year students from the WA School of Mines, University of Queensland and Murdoch University. The session was part of a semester-long course run under the Metallurgical Education Partnership.

Professional Development

CSRP continues to believe that sustainability issues are people issues. **True sustainability can only result from an educated public.** Additionally, CSRP asserts that there can be no research without researchers, nor can there be any employers without employees. It has been a continuing aim of the Education Program to address the shortage of young people choosing careers in the mining, minerals and resource processing industries in Australia. In this light, CSRP continued its community outreach efforts during 2009/10.

This year's efforts were focussed on both teacher professional development and school student contacts. During the seven year term of CSRP, some 1250 teachers, student teachers and other education professionals have participated at some level in one or more professional development events.

During 2009/10, the following school teacher professional development activities were run across Australia, with over 100 additional school teachers participating:

Another in the series of teacher professional development workshops was held on 2 October 2009. The full-day "***Chemistry and Physics of Extractive Metallurgy***" event was held at Murdoch University in Perth, utilising CSRP staff and students. The 14 participating teachers came from as far away as Port Hedland and Bunbury to hear Dr Jim Avraamides' opening talk entitled "*Extractive metallurgy adding value to Australia's resources*". The teachers spent the entire day doing hands-on activities in the pyrometallurgy laboratory with Ken Seymour and Dr Aleks Nikoloski; in the mineral processing laboratory with Andrew Jones and Sam McDonald; and in the hydrometallurgy lab with Graeme Thompson and Sue Farr. The day ended with a wrap-up session facilitated by Dr Dan Churach linking workshop activities to school curriculum. Teachers and workshop facilitators ended their day with a wine and cheese social.

Dr Jim Avraamides was an invited keynote speaker at **Technet 2009**, the annual meeting of the technical staff of Australia's universities held at the University of Western Australia on 25-27 November 2009. His keynote address, "*Re-processing and Re-use of Mine Tailings: Sustaining our mineral resources*", was warmly received by the 250 attendees. Dr Dan Churach and Ken Seymour presented two workshops at Technet 2009, both entitled "*Mineral to Metal: Copper extraction and recycling*". The workshop included a presentation detailing the copper heap leach process and had participants carry out hands-on activities leaching an ore and electrowinning copper from solution.

The Science Teachers Association of Western Australia (STAWA) held their annual "***Future Science***" event at Murdoch University on 7 December 2009 with some 240 teachers in attendance. CSRP co-sponsored two teacher laboratory sessions at the event:

- "*Geopolymers: New building materials from old by-products*" was a 90-minute workshop presented by CSRP students Ross Williams and Will Rickard. This was the first time "test drive" for the geopolymer workshop and it was well received by the teacher participants.
- "*Copper recovery from oxide ores by leaching, cementation and electrowinning*" was a 90-minute professional development activity presented by CSRP staff members Dan Churach and Ken Seymour along with CSRP doctoral candidate Graeme Thompson.

Dr Jim Avraamides gave three student lectures presenting an overview of the industry to the students and CSRP doctoral candidate Graeme Thompson hosted laboratory a series of sessions in pyrometallurgy on 15 January 2010. The 60 participants were part of the **Western Australia Science and Engineering Summer School** held on the Murdoch University campus.

Graeme Thompson presented two workshops entitled "*Mineral to Metal: Copper extraction and recycling*" to the annual **Conference of the Science Teachers Association of Western Australia** (ConSTAWA) held at the Muresk Institute of Agriculture in Northam. Two-dozen teachers participated in the sessions.

A professional development workshop on "***Writing Clear Science***" was held on 8-10 July 2009. It was a joint offering between CSRP and the Parker CRC for Hydrometallurgical Solutions and was presented by Dr Marina Hurley. The three-day course covered the *nuts and bolts* of writing, writing reports and peer-review papers; and writing theses. Twelve students attended the Perth-based course.

School Student Lectures

CSRP and the Extractive Metallurgy department of Murdoch University hosted several groups of high school students during the 2009/10 year. Introductory lectures and laboratory sessions comprised the full-day sessions. Staff involved in presenting these school visits included Dr Dan Churach, Dr Jim Avraamides, Graeme Thompson, Dr Aleks Nikoloski, Ken Seymour, Andrew Jones, Sue Farr and Dr Jai Prasad.

Participating school groups included:

- Australian Student Mineral Venture (Western Region) on 7 July 2009 – 35 year 11 and 12 students
- All Saints College (Bull Creek, WA) on 9 July 2009 – 15 "science extension" high school students
- Nagle Catholic College and Geraldton Grammar School (Geraldton, WA) on 24 September 2009 – 45 year 11 and year 12 WACE/TEE students
- Maranatha Christian College (Rockingham, WA) on 23 June 2010 – 65 year 11 and 12 students

Undergraduate Scholarships

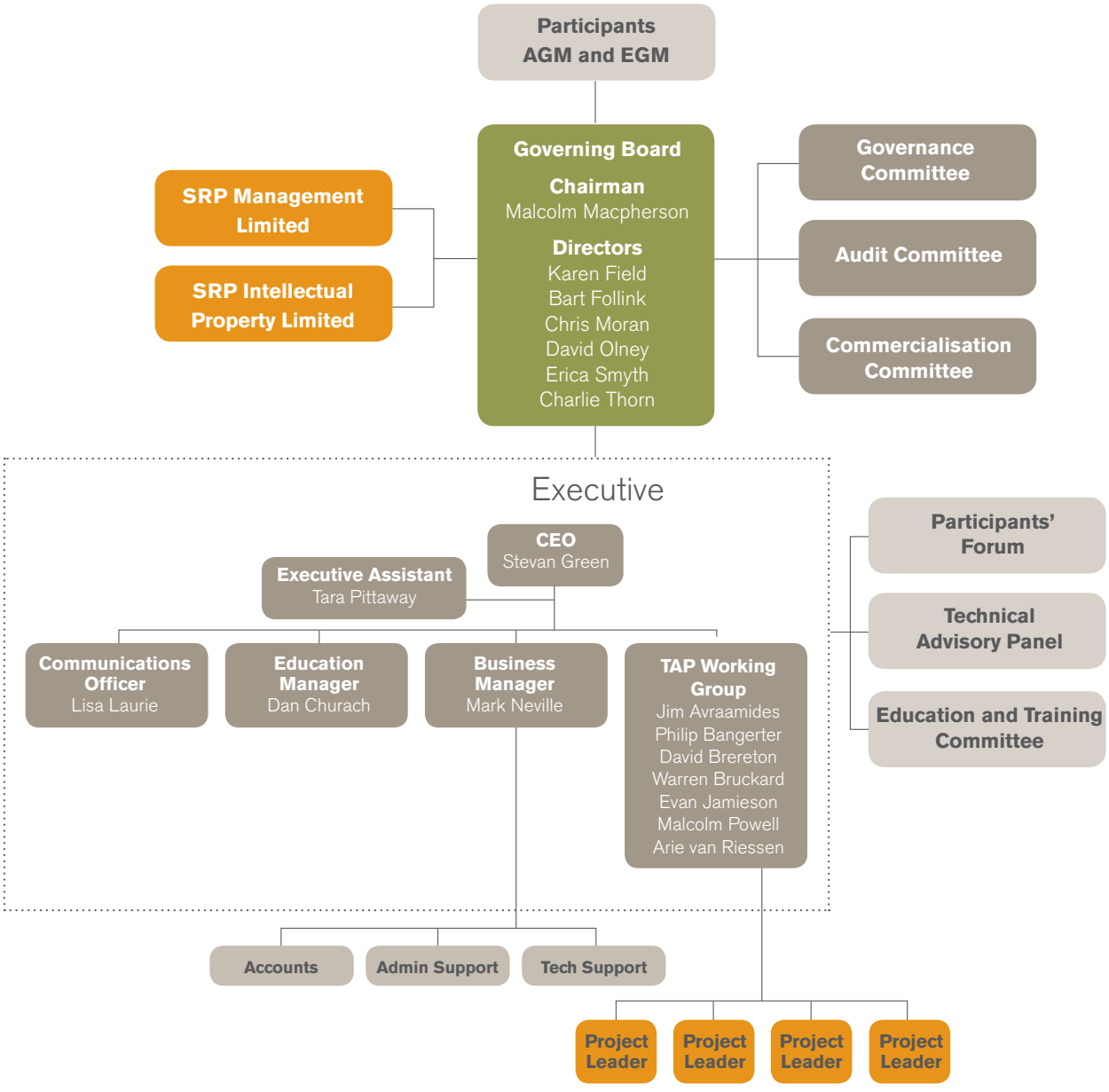
For the past four years, CSRP has awarded scholarships to the most promising first year CSRP students studying Extractive Metallurgy at Murdoch University. Two scholarships of $500 each were given to Rain Murphy and Kristopher Stone and were presented at a department barbecue on 4 November 2009.

CSRP's teacher workshop at ConSTAWA.

Governance and Management

CSRP was established in 2003 under a Commonwealth Agreement administered by the Department of Innovation, Industry, Science and Research. This agreement sets out the outcomes, outputs and milestones to be achieved, the budget and the Participants' obligations.

CSRP is an unincorporated joint venture; however it has adopted governance practices and fiduciary responsibilities consistent with those of an incorporated body. Sustainable Resource Processing Management Ltd was established as an incorporated entity to act as Centre Agent for CSRP. The management company conducts the day to day running of CSRP and provides the management, administration and business functions for CSRP. It employs the Chief Executive Officer and other staff who otherwise might not be appropriately employed within participating organisations. Sustainable Resource Processing Intellectual Property Ltd was also established as an incorporated body to manage the ownership of CSRP's intellectual property and will hold in trust intellectual property developed by CSRP on behalf of its Participants.



Governing Board

The Governing Board consists of an independent chairman, two independent directors, and two representatives each from the research providers and industry Participants. The Governing Board takes overall responsibility for CSRP policy, strategic direction, budget allocation and monitoring, and accountability for all matters relating to the objectives of CSRP and its programs. The Governing Board met three times during 2009/10.

Audit Committee

The Audit Committee is a sub-committee of the Governing Board. It is required to provide advice and assistance to the Governing Board in fulfilling the Board's responsibilities. These include CSRP's internal accounting and financial control systems, external audit, financial statements, financial reporting processes, project expenditure reporting, corporate governance disclosures, and such other matters as the Governing Board may request from time to time. The Audit Committee consists of Karen Field (Chair), Mark Neville, David Olney and Erica Smyth. The Audit Committee met four times during 2009/10.

Commercialisation Committee

The Commercialisation Committee is responsible for providing advice to the Governing Board on the commercialisation of intellectual property arising from the activities of CSRP. The Commercialisation Committee consists of Mark Neville (Chair), with other members recruited as required. The Commercialisation Committee has met informally every month in 2009/10 and informally with commercialisation consultants and lawyers.

Governance Committee

The Governance Committee is responsible for recommending the appointment of the Chief Executive Officer and other Executives, and managing the process for the review of the Directors' performance. It will also advise the Governing Board on other matters relating to corporate governance and will act as a nominations committee to assist in filling Governing Board vacancies as they arise. The Governance Committee consists of Malcolm Macpherson (Chairman) and Karen Field.

Governing Board

Board Member	Organisation	Positions in CSRP	Key Skills
Mr Malcolm Macpherson	Independent	Chairman Governance Committee Chairman	Extensive experience in the titanium minerals industry and the Australian mining sector.
Mrs Karen Field	Independent	Independent Director Audit Committee Chair Governance Committee Member	Consultant with extensive experience in the international mining industry.
Ms Erica Smyth	Independent	Independent Director Audit Committee Member	Extensive experience in project management, government approvals and community consultation in the minerals and oil and gas industries.
Mr Dave Olney	Alcoa	Industry Director Audit Committee Member	Extensive experience in the international alumina processing industry.
Dr Bart Follink	CSIRO Process Science and Engineering	Research Director (until 09/10/2009)	Extensive experience in senior research and general management roles, both in industry and the public sector.
Mr Charlie Thorn	Australian Sustainable Development Institute, Curtin University	Research Director (from 18/02/2010)	Extensive experience in research management, commercialisation and technology transfer in agriculture, fisheries and university research institutions.
Prof Chris Moran	Sustainable Minerals Institute, University of Queensland	Research Director	Extensive experience in natural resource science, agriculture, landscape and water research; and has delivered a range of projects to government and industry.

CEO and Executive

Executive Member	Position in CSRP	Time Allocation
Mr Stevan Green	Chief Executive Officer	1.0
Dr Dan Churach	Education Manager	0.6
Ms Lisa Laurie	Communications Officer	1.0
Dr Mark Neville	Business Manager	1.0

Program Leaders

Program Leader	Organisation	Position in CSRP	Time Allocation
Dr Jim Avraamides	Department of Commerce WA	Research Program Coordinator	0.2
Prof David Brereton	University of Queensland	Sustainable Development Program Leader	0.2
Mr Warren Bruckard	CSIRO	Zero Waste and Minor Elements Program Leader	0.2
Dr Evan Jamieson	Alcoa	Bauxite Residue Program Leader	0.4
Dr Michele Rosano	Curtin University	Regional Synergies Program Leader	0.3
Prof Malcolm Powell	University of Queensland	Energy Efficient Liberation and Comminution Program Leader	1.0
Prof Arie van Riessen	Curtin University	Geopolymer Program Leader	1.0

Technical Advisory Panel

The Technical Advisory Panel (TAP) is responsible for providing a conduit to respective "home" organisations and promoting the activities of CSRP within their organisations and beyond, participating in projects of interest to their organisation by providing advice, access to personnel, site and operational information as appropriate and assisting with the development of research proposals related to their field of operation.

TAP membership is comprised of technical member representatives from all Participants in CSRP:

Alcoa – Dr David Cooling

Alcoa – Dr Evan Jamieson

Anglo Platinum – Mr Neville Plint

ANSTO – Dr Lou Vance

BHP Billiton – Dr Steven Rosenberg

BHP Billiton – Dr Brian Smith

BlueScope Steel – Dr John Mathieson

CSIRO – Mr Warren Bruckard

CSIRO – Dr Sharif Jahanshahi

Curtin University – Assoc Prof Michele Rosano

Curtin University – Prof Arie van Riessen

Department of Environment, Water, Heritage and the Arts – Mr Damien Hall

Department of Commerce WA – Dr Jim Avraamides

Geopolymer Alliance – Dr Terry Gourley

GHD – Dr Dick van Beers

Hatch – Mr Philip Bangerter

Hatch – Mr Andrew Murphy Kwinana Industries Council – Mr Chris Oughton

Minerals Council of Australia – Dr Kevin Tuckwell

Murdoch University – Dr Nimal Subasinghe

Newmont – Mr Aiden Giblett

OneSteel – Mr Phil Ridgeway

Orica – Mr Geoff Brent

Rio Tinto – Mr Chris Goodes

Rio Tinto – Mr Steven Healy

Rocla – Mr Greg Johnson

University of Newcastle – Prof Geoffrey Evans

University of Newcastle – Dr Andrew Johnson

University of Queensland – Prof David Brereton

University of Queensland – Dr Glen Corder

University of Queensland – Prof Chris Moran

University of Queensland – Prof Malcolm Powell

URS – Mr Peter Elliott

Xstrata – Mr Joe Pease

Xstrata – Mr David Way

Technical Advisory Panel Working Group

The purpose of the Technical Advisory Panel Working Group (TAPWG) is to:

- actively participate in the development of coherent programs and projects,
- ensure that Researcher and Industry views are provided for inclusion in all project and program proposals presented to the Governing Board by the Chief Executive Officer,
- ensure that the calibre of the research undertaken is world class,
- act as the day-to-day interface between the research Participants and CSRP,
- assist the Chief Executive Officer with managing CSRP's research activities, and
- interact and communicate with the Technical Advisory Panel.

The industry and research cohorts from each program have developed their own schedule for meetings however it is usually fortnightly or monthly. The combined TAPWG meets fortnightly via teleconferencing and face-to-face each quarter.

TAPWG membership is comprised of the following technical member representatives:

Alcoa – Dr Evan Jamieson

CSIRO – Mr Warren Bruckard

CSRP – Mr Stevan Green (Chair)

Curtin University – Prof Arie van Riessen

Department of Commerce WA – Dr Jim Avraamides

Hatch – Mr Philip Bangerter

University of Queensland – Prof David Brereton

University of Queensland – Prof Malcolm Powell

Participants' Forum

The Participants' Forum acts as an advisory body and provides a forum for consultation among CSRP Participants. The Participants' Forum meets formally on an annual basis, and as otherwise required by the Participants.

Alcoa – Dr David Cooling

Anglo Platinum – Mr Peter Charlesworth

Anglo Platinum – Mr Neville Plint

ANSTO – Dr Lou Vance

BHP Billiton – Dr Steven Rosenberg

BHP Billiton – Dr Brian Smith

BlueScope Steel – Dr John Mathieson

CSIRO – Dr John Rankin

Curtin University – Dr Michele Rosano

Department of Environment, Water, Heritage and the Arts – Mr Damien Hall

Department of Environment, Water, Heritage and the Arts – Mr Barry Reville

GHD – Mr Bill Grace

Hatch – Mr Philip Bangerter (Chair)

Kwinana Industries Council – Mr Chris Oughton

Minerals Council of Australia – Dr Kevin Tuckwell

Murdoch University – Prof Peter May

Newmont – Mr Aiden Giblett

OneSteel – Mr Phil Ridgeway

Orica – Mr Geoff Brent

Rio Tinto – Dr Chris Goodes

Rocla – Mr Mike Lukban

University of Newcastle – Dr Andrew Johnson

University of Queensland – Prof Chris Moran

URS – Mr Peter Elliott

Xstrata – Mr David Way

Education and Training Committee

The Education and Training Committee provides advice on the development of the education and training aspects of CSRP. The Committee meets on an as needs basis and has met once during 2009/10.

Curtin University – Assoc Prof Norm Stockton

CSIRO – Dr Shouyi Sun

Murdoch University/CSRP – Dr Dan Churach (Convenor)

Department of Commerce WA – Dr Jim Avraamides

Minerals Council of Australia – Dr Kevin Tuckwell

University of Queensland – Dr Janine Lay

Changes to Participants

There were no changes to Participants during 2009/10.

Outputs and Milestones

Sustainable Development Program

Output	Description	Achieved	Comments
Output 1.1	A framework of fundamental principles, practical guidelines, indicators, metrics and decision making tools that provide the foundations of sustainable minerals processing and metal production.	Yes	The SUSOP® sustainable development techniques and concepts will be further developed by researchers and industry Participants.
Output 1.2	Topical papers, presentations and books on issues pertinent to industry, research, technology, government and community strategists and practitioners.	Yes	
Output 1.3	Design criteria and guidelines that align with the sustainability framework and are relevant to major projects, including greenfield and brownfield projects and new technology development.	Yes	Refer to Output 1.1
Output 1.4	An innovation model that draws on the sustainability framework and its implicit stretch targets, multi-disciplinary approach and total system/value chain perspectives.	Yes	Refer to Output 1.1
Output 1.5	Tools for technology design and selection based on life cycle thinking and multi-criteria decision analysis.	Yes	
Output 2.1	A practical sustainability framework of principles, guidelines, templates, glossary and metrics for application to mineral processing and metal production.	Yes	
Output 2.2	An eco-efficiency auditing and improvement methodology based on the sustainability framework.	No	An eco-efficiency assessment was performed for one industry Participant. However, project was discontinued as, in general, industry claims that this is already done at the site level.
Output 3.1	Customised methodologies and tools for evaluating material and energy flows in regions and supply chains to identify, evaluate and develop synergies and innovation opportunities.	Yes	
Output 3.2	A methodology for estimating and reporting the net eco-efficiency benefits of proposed or implemented projects across multiple operations (including new revenue streams and net savings in costs, wastes, energy, water, emissions).	Yes (Research conducted outside CSRP)	This Output was covered by a parallel research project on triple-bottom line accounting of regional synergy benefits, funded by the Australian Research Council.
Output 3.3	Technical solutions for beneficiating specific waste and emission streams to provide suitable feed inputs for other processes or value adding products.	Yes	
Output 3.4	A compendium of industrial ecology opportunities that have been technically proven and have wide applicability in the mineral processing sector.	Yes	
Output 3.5	Innovative flowsheets for streamlining selected mineral/metal processing chains.	No	The original CSRP agreement included streamlining of stainless steel production. A review of industry needs and research objectives concluded that this was not a high priority for Australia and would be removed from the CSRP research portfolio.

Milestone	Description	Contracted Achievement Date	Achieved	Comments
Milestone 1.1	Industry 'think tank' in place to mentor and contribute actively to Program 1 in an extended workshop-based process.	Year 1	Yes	
Milestone 1.2	Appropriate historical and living case studies (operations, projects, value chains) agreed for framework development, project design study and innovation model development.	Years 1, 2	Yes	
Milestone 1.3	Critical review of existing sustainability frameworks and status of minerals industry initiatives from the perspective of sustainable resource processing.	Year 1	Yes	
Milestone 1.4	Strategy Workshop to integrate and build on the analytical frameworks, indicators and innovative concepts arising from project work in all Program 1-4.	Years 2, 4, 6	Yes	
Milestone 1.5	Strong CRC involvement in the organisation and content of 'Green Processing', the International Conference on the Sustainable Processing of Minerals.	Years 2, 4, 6	Yes	
Milestone 1.6	Conference for all CRC Participants to review research outputs, share insights and shape future program and project development.	Annually	Yes	
Milestone 1.7	Identification of long term opportunities for significant 'Factor X' improvements in eco-efficiency of overall minerals processing and metals production value chains.	From Year 3	Yes	Technologies developed in mineral processing, metal production, waste utilisation and sustainable development concepts will have significant long term impact.
Milestone 1.8	Publication of user-friendly handbooks on the sustainability framework, design guidelines and innovation model.	Years 2, 3, 4	Yes	Outputs include: Significant contributions to the Materials Stewardship Booklet in the Leading Practice Sustainable Development Program of the Department of Industry, Tourism and Resources; SUSOP® manual; Database of Australian data on electricity generation and transportation; and A guide to publically available tools related to sustainable development in the minerals industry.
Milestone 1.9	An updated strategic R&D plan to inform the Centre's business planning and budgeting processes.	From Year 2	Yes	CSRP's Research Action Plan was reviewed regularly by the Technical Advisory Panel to inform the research agenda.
Milestone 1.10	A qualitative and quantitative review of aggregated Centre achievements.	Annually	Yes	
Milestone 2.2	Agreement with a group of specific operations to co-develop the auditing approach and the generic eco-efficiency methodology.	Year 1	Yes (Partly)	Refer to Output 2.2. Note that one confidential audit was carried out by CSRP in 2006.
Milestone 2.3	A review of eco-efficiency methodologies and best practices in the sponsoring organisations.	Year 1	Yes	
Milestone 2.4	Major workshops on energy and water that synthesise the outputs of the many initiatives in this area.	Years 2, 4, 6	Yes	
Milestone 2.5	Multidisciplinary team audits and improvement exercises completed at particular operations.	From Year 1	Yes	Industry-based SUSOP® case studies completed.
Milestone 2.11	Publication of user-friendly handbooks on eco-efficiency, tailored to operations, with a focus on energy, water, materials accounting, waste and toxic dispersion.	Years 2, 3, 4	Yes	Outputs from the SUSOP® case studies contributed to this Milestone.

Milestone	Description	Contracted Achievement Date	Achieved	Comments
Milestone 2.12	Contributions to the Minerals Council of Australia (MCA) Sustainable Development Conference, and similar industry meetings at state level and globally.	Annual	Yes	
Milestone 2.13	Assessments by sponsoring organisations of the CRC's contribution to improved performance in existing operations.	Years 2, 4, 6	Yes	An independent evaluation of CSRP outputs was conducted in 2008 with input from industry.
Milestone 3.1	Appropriate CRC collaboration model and priorities agreed with Kwinana and Gladstone and project resources allocated.	Year 1	Yes	
Milestone 3.2	Critical evaluation of input-output balance for the Kwinana region, for identification, screening and development of potential synergies, using site-based tools such as PINCH.	Year 2	Yes	
Milestone 3.3	CRC technical and facilitation support to the Gladstone Regional Synergies initiative.	From Year 1	Yes	
Milestone 3.4	Critical assessments of existing and emerging energy and water technologies for their applicability to regional synergies.	Year 4	Yes	
Milestone 3.5	Thermodynamic modelling, bench and pilot test work on unit processes, and integration for economic and life cycle analysis of alternative routes to Ni & stainless steel.	Year 2	No	The original CSRP agreement included streamlining of stainless steel production. A review of industry needs and research objectives concluded that this was not a high priority for Australia and would be removed from the CSRP research portfolio.
Milestone 3.6	Three additional resource processing intense regions to become actively involved in regional synergy projects.	Years 2, 4, 6	Yes	Regional synergies studies carried out in Rustenberg (South Africa), Geelong and South Australia.
Milestone 3.7	Regional Sustainability Workshops to share new best practices, generic opportunities and methodologies and to provide an assessment of CRC contributions/ achievements.	Years 1, 3, 5	Yes	A range of workshops related to water, energy and regional synergies have been conducted at various times during the term of CSRP. Dissemination of CSRP contributions /achievements also includes conference presentations, journal publications and invited presentations.
Milestone 3.8	A methodology for 'greening the supply chain' tested in practice for the first candidate mineral/metal commodity.	Year 3	No	The original CSRP agreement included streamlining of stainless steel production. A review of industry needs and research objectives concluded that this was not a high priority for Australia and would be removed from the CSRP research portfolio.
Milestone 3.9	Identification of at least one big step, realisable improvement opportunity in eco-efficient regional development at both Kwinana and Gladstone (regional showcase projects).	By Year 3	Yes	Opportunities have been identified for Kwinana, Gladstone and Rustenberg (South Africa).
Milestone 3.10	Regional Sustainability Workshops to share new best practices, generic opportunities and methodologies and to provide an assessment of CRC contributions/ achievements.	Years 1, 3, 5	Repeat of Milestone 3.7	

Energy Efficient Liberation and Comminution Program

Output	Description		Achieved	Comments
Output 2.5	Specific energy and water saving technologies which together contribute to significant cost effective reductions in Greenhouse emissions and water impacts in mine site processing, in particular energy efficient liberation.		Yes	
Milestone	**Description**	**Contracted Achievement Date**	**Achieved**	**Comments**
Milestone 2.1	Effective integration of existing AMIRA projects with a focus on energy efficiency and minor element control.	Year 1	Yes	
Milestone 2.6	Critical evaluation of new comminution technologies and approaches to liberation, and mine to mill optimisations of feed preparations, size distributions and waste removal strategies.	From Year 2	Yes	
Milestone 2.10	Identification of least two novel technology approaches for big step eco-efficiency improvements in operations that can be applied in the industry without major capital.	By Year 3	Yes	
Milestone 4.13	A thorough review of significant new technology developments arising from the CRC, their potential value and the progress toward commercialisation.	Years 3, 5, 7	Yes	An independent evaluation of CSRP outputs was conducted in 2008 with input from industry.

CO2 Breakthrough in Metal Production Program

Output	Description		Achieved	Comments
Output 4.5	Viable technology options for the use of biomass, organic waste and renewable sources of energy and reductant in metallurgical processes.		Yes	
Milestone	**Description**	**Contracted Achievement Date**	**Achieved**	**Comments**
Milestone 4.8	The specific processing and product property issues resolved for dry granulation of slags for cements.	Year 2	Yes (in Year 4)	Ongoing pilot and plant trials with industry are planned to continue beyond the term of CSRP.
Milestone 4.10	Technical feasibility demonstrated for viable use of biomass and other carbonaceous waste materials as effective reductants and fuel in bath smelting processes, including for production of bulk clean fuels of future.	Year 5	Yes (Partly)	Only limited work on bulk fuels.
Milestone 4.11	A critical review of the potential to use biomass, organic waste and renewables in metallurgical processing and an analysis of the key R&D issues to address.	Year 2	Yes	
Milestone 4.12	A foundation of fundamental work on biomass pyrolysis, carbon morphologies, and behaviour in metallurgical reactions.	Year 5	Yes	

Bauxite Residue Program

Output	Description		Achieved	Comments
Output 4.4	Specific technologies to enable the widespread use of bauxite residues as economic co-products of the Bayer process.		Yes	
Milestone	**Description**	**Contracted Achievement Date**	**Achieved**	**Comments**
Milestone 4.2	Assessment and development of cost effective solutions for dewatering/drying, compacting and transporting of residues.	Year 3	Yes	ReSand® produced from bauxite residue at a 10 tph pilot plant. Trials and demonstrations of residue used as road base, nutrient filter and soil amendment completed. Geopolymer concrete trials completed.
Milestone 4.9	Techno-economic, 'triple bottom line' evaluation of existing, emerging and embryonic technology options for neutralising bauxite residues.	Year 1	Yes (in Year 3)	

Geopolymer Program

Output	Description		Achieved	Comments
Output 4.2	A robust technology platform (processing and final properties) for the production of geopolymer products containing significant volumes of mineral wastes, as a low GHG alternative to Portland cement-based concretes.		Yes	
Output 4.3	Processing conditions and product properties for the enhanced conversion of slags and wastes into value adding cement products.		Yes	
Milestone	**Description**	**Contracted Achievement Date**	**Achieved**	**Comments**
Milestone 4.5	Experimental work on the candidate geopolymer feed materials has identified the most promising combinations.	Year 2	Yes	
Milestone 4.6	Clarification of the chemistry and kinetics of geopolymer production, based on the specific features of feedstocks, and the link to final product properties.	Year 4	Yes	
Milestone 4.7	Large scale production and marketing trial for geopolymer material with significant metallurgical waste content.	Year 5	Yes (Partly)	Trials will continue beyond the term of CSRP in precast geopolymer products (pipes, railway sleepers) and premix pathways.

Zero Waste and Minor Elements Program

Output	Description	Achieved	Comments
Output 2.3	A comprehensive and critical analysis of minor element deportment in mineral processing and metal production chain case studies, with technical solutions to maximise overall value recovery and minimise toxic dispersion.	Yes (Partly)	Complete data sets are difficult to obtain at many sites.
Output 2.4	Mass, energy, elemental, energy, consumable, water and reagent balances in selected mine to metal/refined mineral processing chains.	Yes (Partly)	Complete data sets are difficult to obtain at many sites. Balances were only carried out at sites if required for R&D effort.
Output 4.1	Viable integrated process designs for converting prevalent metallurgical residues and wastes into a valuable combination of metals, chemicals, clean energy, steel and building and construction materials.	Yes (Ongoing)	Work in this area continues on a number of fronts (e.g. bauxite residue, sulphide tailings, slags) beyond the term of CSRP.

Milestone	Description	Contracted Achievement Date	Achieved	Comments
Milestone 2.7	A comprehensive analysis of NORMs and heavy metal deportment in specific mine to product processing chains.	From Year 2	Yes (Partly)	Project 2D9, through the AMIRA P970 project, continues work on arsenic removal.
Milestone 2.8	An analysis of minor element behaviour in base metal smelting identifying opportunities for optimisation.	Year 2	Yes	
Milestone 2.9	A thorough exploration of new approaches to pre-concentration, concentrate pre-treatments, selective leaching and process re-design for early removal and capture of toxic substances.	Year 4	Yes	
Milestone 4.1	Identification and physical/chemical characterisation of the most prevalent metallurgical wastes in Australia with parallel hypothesis generation for promising treatment options.	Year 1	Yes	
Milestone 4.3	Comprehensive and rigorous process modelling of preferred zero waste flowsheet, supported by laboratory scale test work and life cycle evaluation of costs and benefits.	Year 2	Yes	
Milestone 4.4	Zero waste smelting concept demonstrated at pilot scale with real mineral industry waste feeds and saleable outputs.	Year 5	No	Australian waste producers are pursuing other technology options.

Education and Training

Output	Description	Achieved	Comments
Output 5.1	Some 26 PhD and 26 Masters students completing their courses and projects over the life of the CRC.	Yes	Though the mix of PhD and masters was different from the original KPIs, the final totals of completed PhD, masters and Honours will have exceeded the targets.
Output 5.2	Vocational training packages geared toward operators and technicians working in mineral processing and metal production sites.	Yes	
Output 5.3	Teaching units that contribute to Graduate Diploma and Masters degree courses in sustainable resource processing.	Yes	
Output 5.4	Papers, booklets, books, conference presentations, business seminars and electronic communications that give the CRC a high education profile.	Yes	
Output 5.5	Education units for the Minerals Tertiary Education Council program.	Yes	

Milestone	Description	Contracted Achievement Date	Achieved	Comments
Milestone 5.1	Effective operation of the Education Committee and the development of a comprehensive program of education and training activities.	Year 1	Yes	
Milestone 5.2	Graduate course modules in sustainability and the minerals industry designed, developed and piloted, and ready for all students and most professionals engaged with the CRC.	Year 2	Yes	
Milestone 5.3	Vocational course modules piloted, and packaged for distance learning at operating sites.	Year 2	Yes	
Milestone 5.4	Postgraduate student recruitment at the rate needed to meet business plan targets.	Annually	Yes	
Milestone 5.5	Effective CRC intra and internet communication in place, with an excellent CRC website.	Year 1	Yes	

Milestone	Description	Contracted Achievement Date	Achieved	Comments
Milestone 5.6	Participants Conference of the CRC.	Annually	Yes	
Milestone 5.7	A successful 'Green Processing' International Conference on Sustainable Minerals Processing.	Years 2,4,6	Yes	
Milestone 5.8	Establishment of regional nodes for the CRC in Brisbane, Sydney and Melbourne to provide a focus for seminars, courses and workshops.	Year 1	Yes	

Commercialisation and Utilisation

Output	Description		Achieved	Comments
Output 6.1	Specific development, IP management and commercialisation plans for each technology to be commercialised.		Yes	Completed as part of the CSRP wind-up.
Milestone	**Description**	**Contracted Achievement Date**	**Achieved**	**Comments**
Milestone 6.1	Intellectual property issues addressed at the project level.	From Year 1	Yes	
Milestone 6.2	A coherent commercialisation strategy for the CRC in place.	By Year 2	Yes	
Milestone 6.3	Formation of the Commercialisation Committee to advise the Governing Board.	Year 1	Yes	

Performance Measures

CRC Program Objective 1: To enhance the contribution of long-term scientific and technological research and innovation to Australia's sustainable economic and social development.		
CSRP Objective 1.1: To mobilise an effective, innovative and world class R&D response to the sustainability challenges facing the minerals processing industry.		
Performance Measures 1.1: Our R&D performance will be judged by our peers and stakeholders, in Australia and globally. This will be tracked by:		
	2008/09	**2009/10**
Publications (numbers and quality), invitations (e.g. keynote lectures), citations, awards, global research collaborations.	CSRP continues to publish extensively with over 160 publications in 2008/09 compared with 120 the previous year. This includes 54 refereed publications and 32 media articles. We now have a total of over 560 publications since inception. We also continue to have our performance recognised by our peers and stakeholders: • PhD student in the top four presenters at the CRC Association's Showcasing Early Career Scientists event in May 2009. • The number of collaborators and level of funding (local and international) remains steady. • Various letters from industry in support of our current work and continuation through the CRC Program.	In our final year of operation, we produced over 145 publications compared with 160 the previous year. This includes 59 refereed publications and 34 media articles. We now have a total of over 700 publications since inception. We also continued to have our performance recognised by our peers and stakeholders: • PhD student awarded "best paper" at the Goldfields Environmental Management Group conference in May 2010. • All Participants continued to work with CSRP in our final year. • Various letters from industry in support of our work. • PhD student awarded the "2010 Vittorio de Nora Prize for Environmental Improvements in Metallurgical Industries"
The credibility and relevance of our scientific work within industry and government circles (testimonials from industry and government leaders, inclusion of CSRP in official company and government literature).		
Number of companies using CSRP as the preferred research provider for sustainability-related research (proportion of maximum market potential).		
The growth of new research funding.		

CRC Program Objective 2: To enhance the transfer of research outputs into commercial or other outcomes of economic, environmental or social benefit to Australia.		
CSRP Objective 2.1: To create a realisable vision for a sustainable minerals processing and metal production industry with a fraction of current ecological impacts and to develop a framework of analysis that can guide progress toward that goal.		
Performance Measures 2.1: Our performance will be judged by:		
	2008/09	**2009/10**
The extent that industry, government and community stakeholders share the strategic vision.	• Moving into our final year of operation, we continue to have 23 Participants and over 40 project affiliates. • CSRP researchers accepted five invitations to present on topics at three international conferences. • As a co-sponsor and part of the organising committee, CSRP played a key role in the Sustainable Development Indicators for the Minerals Industry (SDIMI) 2009 conference on the Gold Coast – held for the first time outside Europe. CSRP also facilitated a Sustainability Assessment Forum during the conference. • CSRP, along with other international collaborators, has helped fund the world's most sensitive Positron Emission Particle Tracking (PEPT) facility in Cape Town, South Africa.	• In our final year of operation, we retained our 23 Participants and over 30 project affiliates. • CSRP researchers accepted 3 invitations to present on topics at 3 international conferences. • CSRP completed two live SUSOP® case studies with BHP Billiton to identify sustainability opportunities and benefits at two separate mine sites. • CSRP received acknowledgements at various international conferences for our contribution to sustainability in the minerals industry. • The Positron Emission Particle Tracking facility in Cape Town, South Africa had its official opening. The facility has been operating throughout the year and has been used to carry out work for some CSRP comminution projects and other industry sponsored projects. • SUSOP® foundation manual completed.
The extent to which we and others can understand and apply the framework of analysis, methodologies and metrics to inspire, evaluate and implement innovative processing options.		
Our contribution to finding economically and socially attractive ways to eliminate waste and emissions from the minerals processing sector as a whole.		
Aggregate listings of the number and potential value of viable improvements arising from the CRC, including in-process changes that reduce waste, capture emissions and better utilise material, heat and water resources; benign reagent substitution for toxic inputs and precursors; inerting hazardous residues, conversion into useful products or feedstocks.		
Adoption of CRC outputs and analysis framework, as reflected in company annual HSEQC and sustainability reports.		

CSRP Objective 2.2: To enhance the eco-efficiency of existing minerals processing and metals production operations.

Performance Measures 2.2: Our performance will be judged by our ability to provide technical solutions, methodologies and education, which improve the overall performance of existing operations. Quantitative and qualitative measures will track project outcomes with respect to the combined impacts on:

	2008/09	**2009/10**
Operating costs and revenues Resource utilisation and materials efficiency Energy use and greenhouse gas emissions Water use and impacts Minor element control and toxic emissions	The value of our research to existing and new operations has been demonstrated by the following: • Supplied over 2,500 cubic metres of ReSand® to Main Roads WA for use in the widening of a road south of Perth. • Bauxite residue used in a nutrient trap application. Initial analysis of the data looks promising. • Utilisation of fly ash geopolymers as a fireproofing material. • JKRBT breakage characterisation device has been used extensively in the development of new rock fracture theories to help reduce the overall energy requirements in comminution. • Charcoal (from biomass) used in steelmaking at the OneSteel Sydney Steel Mill.	The value of our research to existing and new operations has been demonstrated by the following: • ReSand® from bauxite residue has proven to be an excellent embankment and subgrade construction material with strength properties that greatly exceed those of the sand normally used in the Perth region. • Nutrient stripping filter constructed from bauxite residue and gypsum has been effective in controlling pH and removing phosphorus and other contaminants from surface water. • Second geopolymer concrete path was cast in November 2009 using a blend of two Australian fly ashes. • A versatile, user-friendly sustainability calculator to compare selected sustainable development metrics for geopolymer concretes with Portland cement concretes.

CSRP Objective 2.3: To enhance the overall eco-efficiency of resource processing intense regions and complex material supply chains in which minerals processing and metals production operations are an integral and important part.

Performance Measures 2.3: Our performance will be judged by:

	2008/09	**2009/10**
Our ability to innovate across boundaries to provide technical solutions, industry ecologies, methodologies and coordination initiatives that contribute to the sustainable development of regions and the streamlining and optimisation of supply chains. In this case, performance measures will reflect our contribution to improvements in the eco-efficiency of groups of operations and businesses collectively, including net waste reductions, process and non-process, number of linkages between industries, and net energy and raw materials use efficiencies.	• Two spin-off projects have been funded by CSRP as a result of the "Capturing Regional Synergies in Kwinana Industrial Area" (3B1 Extension) work. The new projects are on an evaporative seawater desalination system, and potential effluent synergies in the Kwinana Industrial Area. • With CSRP's support, the world's most sensitive Positron Emission Particle Tracking camera has been donated to the University of Cape Town and CSRP has contributed funds to establishing the resultant PEPT facility.	• Two spin-off projects now complete. • Identification of two possible sites with suitable waste heat sources and the preferred technology for a demonstration desalination plant. Collaborative demonstration desalination project to be carried out by industry collaborators. • Evaluation of synergy opportunities submitted to the Kwinana Industries Council in April 2009. Industry partners to determine the synergies that are most likely to be supported by the industries in the Kwinana Industrial Area.

CSRP Objective 2.4: To develop new technologies that enable breakthroughs to be made towards zero net waste and emissions in minerals processing and metals production.

Performance Measures 2.4: Our performance will be judged by the number and potential benefits of new process and product innovations that:

	2008/09	**2009/10**
Are shown to be technically and economically feasible. Have a viable development and commercialisation strategy in place.	A number of technologies have been demonstrated in field and plant trials including: • ReSand® from bauxite residue used for road construction, top dressing and a nutrient trap. • Utilisation of fly ash from coal-fired power stations to make low greenhouse gas geopolymer concrete. • JK Rotary Breakage Tester has been developed, manufactured in Australia and marketed. Seven units already deployed worldwide. • Concept of integrated dry granulation and heat recovery has been successfully demonstrated through a prototype pilot facility. Dry granulated slags have good cementitious properties and are suitable for cement production.	A number of technologies have a commercialisation strategy in place, including: • Commercialisation deed addressing production of ReSand® signed with Alcoa. • Dry Slag Granulation technology assigned to project Participants to allow further development towards commercialisation. • Geopolymer Alliance and Geopolymer Foundation established to promote the uptake of geopolymer technology the building and construction industry. The Alliance has 13 founding members. • Austeng (a special purpose engineering company based in regional Victoria) have teamed with Rocla on a project to construct geopolymer concrete burial crypts.

CRC Program Objective 3: To enhance the value to Australia of graduate researchers.

CSRP Objective 3.1: To generate a special breed of graduates and industry professionals who combine technical excellence with an understanding of sustainability and are well prepared for leadership as managers or technologists.

Performance Measures 3.1: Our performance will be judged by the number and quality of graduate researchers that:

	2008/09	**2009/10**
Number of students enrolled	33	28
Number of completions (Honours, Masters, PhD) (cumulative)	42 (6 PhD, 6 MSc, 30 Hons)	84 (9 PhD, 6 MSc, 31 Hons, 38 Undergrad)
Number of graduates obtaining employment within the minerals industry and its supporting R&D community (cumulative)	42	75
Number that operate in a multidisciplinary environment (per year) (supervisors from different organisations or alternative location to supervisor)	20	19
Benefit from exposure to complex industrial, social and environmental issues	33	28

CRC Program Objective 4: To enhance collaboration among researchers, between researchers and industry or other users, and to improve efficiency in the use of intellectual and other research resources.

CSRP Objective 4.1: To create a multidisciplinary research, government and industry network capable of working in effective partnership around common objectives.

Performance Measures 4.1: We will be judged by the extent to which valued outcomes draw on the combined talents and intellectual capital of the diverse Participants. Our ability to collaborate effectively will be tracked by:

	2008/09 $'000	**2009/10 $'000**
The growth in industry funding for collaborative projects (represents total industry funding received for collaborative projects).	$3,180	$2,537
Project level cooperation between research organisations (projects with 2 or more institutions collaborating).	11	13
Industry involvement in program development, project activities, education, and joint supervision.	18 projects with direct industry participation. All projects continue to have at least one Industry Champion.	17 projects with direct industry participation. All projects had at least one Industry Champion.

Publications List

Journals

1. Ballantyne, GR and Holtham, PN (2010) "Application of dielectrophoresis for the separation of minerals", *Minerals Engineering*, vol. 23, no. 4, March 2010, pp. 350-358, published online 9 October 2009, http://dx.doi.org/10.1016/j.mineng.2009.09.001
2. Cleary, PW (2009) "Ball motion, axial segregation and power consumption in a full scale two chamber cement mill", *Minerals Engineering*, vol. 22, no. 9-10, August/September 2009, pp. 809-820, http://dx.doi.org/10.1016/j.mineng.2009.02.005 (CSRP Project **2B1** Extension)
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Conference Presentations

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62. Bruckard, WJ and McCallum, DA (2009) "The development of a diagnostic protocol for the assessment and testing of sulfide tailings in relation to future sustainable tailings management", presented at *Enviromine 2009*, Santiago, Chile, 30 September - 2 October 2009 (CSRP Project **4A1**)

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64. Chowdhury, AA, Rasul, MG and Khan, MMK (2009) "An analysis of the indoor air quality and mould growth in a multi-zone model of library building", presented at *Conference on the Challenges in Environmental Science and Engineering (CESE 2009)*, Townsville, Australia, 14-17 July 2009

65. Cocks, R (2009) "A water audit of Newmont's Tanami granites operation", presented at *World Gold Conference 2009*, Gauteng, South Africa, 26-30 October 2009

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Workshop Presentations

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102. CSRP SD Project Group (2010) "SUSOP® familiarisation and SUSID workshop", presented to *BHP Billiton Stainless Steel Materials*, Perth, Australia, 10-12 February 2010 (CSRP Project **101**)

103. CSRP SD Project Group (2010) "SUSOP® prioritisation workshop", presented to *BHP Billiton Stainless Steel Materials*, Perth, Australia, 14-16 April 2010 (CSRP Project **101**)

104. Temuujin, J, Rickard, W, Lee, M and van Riessen, A (2009) "Preparation and properties of fire resistant geopolymer type coatings on metal substrates", presented at *Annual CSRP Geopolymer Meeting*, Perth, Australia, 15-16 July 2009 (CSRP Project **4B1** Extension)

Invited Papers

105. Avraamides, J (2009) "Re-processing and re-use of mine tailings: Sustaining our mineral resources", presented at *TechNet 2009*, Perth, Australia, 25-27 November 2009 **(invited)**

106. Powell, M (2010) "Better comminution performance at lower cost? Yes, it is possible", presented at *Mineral Processing Conference 2010 (Minproc'10)*, Cape Town, South Africa, 5-6 August 2010 **(invited)**

107. Powell, MS and Weerasekara, N (2009) "Challenges in developing a mechanistic breakage model such as the UCM", presented at *European Symposium on Comminution and Classification*, Espoo, Finland, 15-18 September 2009 (CSRP Project **67**, **2B1** Extension) **(invited plenary)**

Pending

108. Chowdhury, AA, Rasul, MG and Khan, MMK **(pending)** "Indoor air quality and mould growth in a multi-zone model of library building: A case study", submitted to *Water, Air, & Soil Pollution: Focus*

109. Delaney, GW, Cleary, PW, Hilden, M and Morrison, R **(pending)** "Testing the validity of the spherical DEM model in simulating real world granular screening processes", submitted to *Chemical Engineering Science* (CSRP Project **2B11**)

110. Khanal, M and Powell, MS **(pending)** "Energy representation for the Unified Comminution Model", submitted to *Particulate Science and Technology* (CSRP Project **67**, **2B1** Extension)

111. McLellan, BC, Williams, RP, Lay, J, van Riessen, A and Corder, GD **(pending)** "Sustainability metrics for Geopolymer pastes in comparison to Ordinary Portland Cement: Australia", (submitted) (CSRP Project **4B1** Extension)

112. Rezaeizadeh, M, Fooladi, M, Powell, MS, Mansouri, SH and Weerasekara, NS **(pending)** "A new predictive model of lifter bar wear in mills", submitted to *Minerals Engineering* (CSRP Project **67**)

113. Sinnott, MD, Cleary, PW and Morrison, RD **(pending)** "Slurry flow in a tower mill", submitted to *Minerals Engineering* (CSRP Project **2B1** Extension)

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Financial Information Table 1– In-Kind Contributions (dollars in $'000)

	Actual														Totals to 2009-10			Totals for 7 years		
	2003-04		2004-05		2005-06		2006-07		2007-08		2008-09		2009-10							
	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Diff	Actual/Proj	Agr'mt	Diff
Core participants																				
Alcoa of Australia Ltd																				
Salaries	45	138	111	138	184	138	323	138	270	138	239	138	78	138	1,250	966	284	1,250	966	284
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	86	263	159	263	305	263	580	263	994	263	799	263	115	263	3,038	1,841	1,197	3,038	1,841	1,197
Total	131	401	270	401	489	401	903	401	1,264	401	1,038	401	193	401	4,288	2,807	1,481	4,288	2,807	1,481
Australian Nuclear Science and Technology Organisation																				
Salaries	35	146	174	0	150	0	128	0	149	0	36	0	0	0	672	146	526	672	146	526
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	48	204	243	0	210	0	178	0	209	0	51	0	0	0	939	204	735	939	204	735
Total	83	350	417	0	360	0	306	0	358	0	87	0	0	0	1,611	350	1,261	1,611	350	1,261
BHP Billiton Nickel West PTY LTD (formerly Western Mining Corporation Resources Ltd)																				
Salaries	24	21	35	21	22	21	12	21	24	21	13	21	9	21	139	147	-8	139	147	-8
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	36	29	49	29	36	29	16	29	33	29	19	29	22	29	211	203	8	211	203	8
Total	60	50	84	50	58	50	28	50	57	50	32	50	31	50	350	350	0	350	350	0
CSIRO																				
Salaries	405	524	375	524	513	524	1,030	524	716	524	751	524	261	524	4,051	3,668	383	4,051	3,668	383
Capital	0	0	0	0	0	0	19	0	0	0	0	0	0	0	19	0	19	19	0	19
Other	567	1,237	525	1,237	719	1,237	1,441	1,237	1,002	1,237	1,052	1,237	365	1,237	5,671	8,659	-2,988	5,671	8,659	-2,988
Total	972	1,761	900	1,761	1,232	1,761	2,490	1,761	1,718	1,761	1,803	1,761	626	1,761	9,741	12,327	-2,586	9,741	12,327	-2,586
Curtin University of Technology																				
Salaries	147	165	243	165	398	165	225	165	484	165	514	165	414	165	2,425	1,155	1,270	2,425	1,155	1,270
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	205	562	340	562	556	562	316	562	677	562	719	562	580	562	3,393	3,934	-541	3,393	3,934	-541
Total	352	727	583	727	954	727	541	727	1,161	727	1,233	727	994	727	5,818	5,089	729	5,818	5,089	729
Newmont Australia Ltd																				
Salaries	10	38	7	38	12	38	8	38	8	38	16	38	5	38	66	266	-200	66	266	-200
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	34	68	14	68	21	68	12	68	13	68	30	68	8	68	132	476	-344	132	476	-344
Total	44	106	21	106	33	106	20	106	21	106	46	106	13	106	198	742	-544	198	742	-544
Technological Resources Pty Ltd																				
Salaries	13	0	27	0	49	0	19	0	10	0	6	0	5	0	129	0	129	129	0	129
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	27	0	58	0	78	0	32	0	18	0	8	0	8	0	229	0	229	229	0	229
Total	40	0	85	0	127	0	51	0	28	0	14	0	13	0	358	0	358	358	0	358
The University of Queensland																				
Salaries	220	167	265	167	308	167	433	167	592	167	642	167	488	167	2,948	1,169	1,779	2,948	1,169	1,779
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	307	415	372	415	431	415	605	415	828	415	898	415	683	415	4,124	2,905	1,219	4,124	2,905	1,219
Total	527	582	637	582	739	582	1,038	582	1,420	582	1,540	582	1,171	582	7,072	4,074	2,998	7,072	4,074	2,998
University of Sydney																				
Salaries	112	198	85	198	45	198	0	198	0	198	0	198	0	198	242	1,386	-1,144	242	1,386	-1,144
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	157	384	119	384	64	384	0	384	0	384	0	384	0	384	340	2,688	-2,348	340	2,688	-2,348
Total	269	582	204	582	109	582	0	582	0	582	0	582	0	582	582	4,074	-3,492	582	4,074	-3,492

Xstrata Queensland Limited																					
Salaries	50	56	9	56	8	56	10	56	25	56	16	56	13	56	131	392	-261	131	392	-261	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	72	99	16	99	11	99	18	99	38	99	45	99	18	99	218	693	-475	218	693	-475	
Total	122	155	25	155	19	155	28	155	63	155	61	155	31	155	349	1,085	-736	349	1,085	-736	
Total in-kind from core participants																					
Salaries	1,061	1,453	1,331	1,307	1,689	1,307	2,188	1,307	2,278	1,307	2,233	1,307	1,273	1,307	12,053	9,295	2,758	12,053	9,295	2,758	
Capital	0	0	0	0	0	0	19	0	0	0	0	0	0	0	19	0	19	19	0	19	
Other	1,539	3,261	1,895	3,057	2,431	3,057	3,198	3,057	3,812	3,057	3,621	3,057	1,799	3,057	18,295	21,603	-3,308	18,295	21,603	-3,308	
Total	2,600	4,714	3,226	4,364	4,120	4,364	5,405	4,364	6,090	4,364	5,854	4,364	3,072	4,364	30,367	30,898	-531	30,367	30,898	-531	
Supporting participants																					
Ausmelt																					
Salaries	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	42	-42	0	42	-42	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	0	14	0	14	0	14	0	14	0	14	0	14	0	14	0	98	-98	0	98	-98	
Total	0	20	0	20	0	20	0	20	0	20	0	20	0	20	0	140	-140	0	140	-140	
Central TAFE																					
Salaries	31	18	24	18	22	18	32	18	0	18	0	18	0	18	109	126	-17	109	126	-17	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	43	28	33	28	30	28	44	28	0	28	0	28	0	28	150	196	-46	150	196	-46	
Total	74	46	57	46	52	46	76	46	0	46	0	46	0	46	259	322	-63	259	322	-63	
Delta EMD Australia Pty Limited																					
Salaries	0	7	0	7	0	7	0	7	0	7	0	7	0	7	0	49	-49	0	49	-49	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	0	13	0	13	0	13	0	13	0	13	0	13	0	13	0	91	-91	0	91	-91	
Total	0	20	0	20	0	20	0	20	0	20	0	20	0	20	0	140	-140	0	140	-140	
Environment Australia																					
Salaries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Gladstone Area Industry Network																					
Salaries	4	8	10	8	9	8	7	8	0	8	0	8	0	8	30	56	-26	30	56	-26	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	5	13	14	13	12	13	9	13	0	13	0	13	0	13	40	91	-51	40	91	-51	
Total	9	21	24	21	21	21	16	21	0	21	0	21	0	21	70	147	-77	70	147	-77	
Hatch Associates Pty Ltd																					
Salaries	12	8	18	8	20	8	23	8	15	8	18	8	16	8	122	56	66	122	56	66	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	17	13	24	13	27	13	37	13	24	13	25	13	22	13	176	91	85	176	91	85	
Total	29	21	42	21	47	21	60	21	39	21	43	21	38	21	298	147	151	298	147	151	
Kwinana Industry Council																					
Salaries	6	8	26	8	28	8	61	8	60	8	63	8	66	8	310	56	254	310	56	254	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	34	12	36	12	61	12	105	12	103	12	109	12	113	12	561	84	477	561	84	477	
Total	40	20	62	20	89	20	166	20	163	20	172	20	179	20	871	140	731	871	140	731	
Minerals Council of Australia																					
Salaries	8	8	10	8	2	8	2	8	2	8	3	8	6	8	33	56	-23	33	56	-23	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	11	13	19	13	3	13	2	13	3	13	4	13	9	13	51	91	-40	51	91	-40	
Total	19	21	29	21	5	21	4	21	5	21	7	21	15	21	84	147	-63	84	147	-63	
NSW Minerals Council Limited																					
Salaries	8	8	3	8	0	8	0	8	0	8	0	8	0	8	11	56	-45	11	56	-45	
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Other	21	13	4	13	0	13	0	13	0	13	0	13	0	13	25	91	-66	25	91	-66	
Total	29	21	7	21	0	21	0	21	0	21	0	21	0	21	36	147	-111	36	147	-111	





Onesteel Limited																				
Salaries	5	26	6	26	9	26	21	26	27	26	47	26	0	26	115	182	-67	115	182	-67
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	10	49	12	49	15	49	34	49	42	49	368	49	0	49	481	343	138	481	343	138
Total	15	75	18	75	24	75	55	75	69	75	415	75	0	75	596	525	71	596	525	71
Other industry participants																				
Salaries	41	508	28	508	35	508	177	508	188	508	188	508	82	508	739	3,556	-2,817	739	3,556	-2,817
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	67	906	47	906	52	906	263	906	305	906	324	906	119	906	1,177	6,342	-5,165	1,177	6,342	-5,165
Total	108	1,414	75	1,414	87	1,414	440	1,414	493	1,414	512	1,414	201	1,414	1,916	9,898	-7,982	1,916	9,898	-7,982
ROCLA INDUSTRIES PTY LIMITED																				
Salaries	7	18	0	18	12	18	22	18	39	18	9	18	21	18	110	126	-16	110	126	-16
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	11	33	17	33	17	33	30	33	61	33	12	33	30	33	178	231	-53	178	231	-53
Total	18	51	17	51	29	51	52	51	100	51	21	51	51	51	288	357	-69	288	357	-69
Tesla Technologies Pty Ltd																				
Salaries	2	8	0	8	0	8	0	8	0	8	0	8	0	8	2	56	-54	2	56	-54
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	2	13	0	13	0	13	0	13	0	13	0	13	0	13	2	91	-89	2	91	-89
Total	4	21	0	21	0	21	0	21	0	21	0	21	0	21	4	147	-143	4	147	-143
URS Australia Pty Ltd																				
Salaries	10	8	4	8	7	8	7	8	5	8	25	8	41	8	99	56	43	99	56	43
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	14	13	6	13	9	13	9	13	7	13	35	13	56	13	136	91	45	136	91	45
Total	24	21	10	21	16	21	16	21	12	21	60	21	97	21	235	147	88	235	147	88
WA State Industry and Technology																				
Salaries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total in-kind from supporting participants																				
Salaries	134	639	129	639	144	639	352	639	336	639	353	639	232	639	1,680	4,473	-2,793	1,680	4,473	-2,793
Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	235	1,133	212	1,133	226	1,133	533	1,133	545	1,133	877	1,133	349	1,133	2,977	7,931	-4,954	2,977	7,931	-4,954
Total	369	1,772	341	1,772	370	1,772	885	1,772	881	1,772	1,230	1,772	581	1,772	4,657	12,404	-7,747	4,657	12,404	-7,747
Other in-kind non-participants																				
Salaries	56		65		98		96		129		151		112		707	0	707	707	0	707
Capital	0		0		0		0		0		0		0		0	0	0	0	0	0
Other	78		104		138		137		182		214		517		1,370	0	1,370	1,370	0	1,370
Total	134	0	169	0	236	0	233	0	311	0	365	0	629	0	2,077	0	2,077	2,077	0	2,077
Total in-kind contributions																				
Salaries	1,251	2,092	1,525	1,946	1,931	1,946	2,636	1,946	2,743	1,946	2,737	1,946	1,617	1,946	14,440	13,768	672	14,440	13,768	672
Capital	0	0	0	0	0	0	19	0	0	0	0	0	0	0	19	0	19	19	0	19
Other	1,852	4,394	2,211	4,190	2,795	4,190	3,868	4,190	4,539	4,190	4,712	4,190	2,665	4,190	22,642	29,534	-6,892	22,642	29,534	-6,892
Grand total in-kind (T1)	**3,103**	**6,486**	**3,736**	**6,136**	**4,726**	**6,136**	**6,523**	**6,136**	**7,282**	**6,136**	**7,449**	**6,136**	**4,282**	**6,136**	**37,101**	**43,302**	**-6,201**	**37,101**	**43,302**	**-6,201**

Notes

For 2009-10 financial year

1) Core Participants in-kind contributions are $531k below budget for the seven years of operation. Supporting Participants contributions (excluding "Other Industry Participants") are $235k above budget for the seven years of operation. Other in-kind contributions from non-participants amounted to $2.077M for the seven years of operation.

2) Refer to the Audit Report and Additional Note - In-kind Industry Funded Activities by Other Industry Participants (UNAUDITED) for information regarding the apparent shortfall between actual and budget cash and in-kind contributions for line items "Other Industry Participants".

Financial Information Table 2 – Cash Contributions (dollars in $'000)

	Actual														Totals to 2009-10			Totals for 7 years		
	2003-04		2004-05		2005-06		2006-07		2007-08		2008-09		2009-10							
	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Diff	Actual/Proj	Agr'mt	Diff
Core participants																				
Alcoa of Australia Ltd	47	400	557	400	291	400	448	400	427	400	484	400	391	400	2,645	2,800	-155	2,645	2,800	-155
Australian Nuclear Science and Technology Organisation	50	50	50	50	50	50	50	50	50	50	50	50	0	50	300	350	-50	300	350	-50
BHP Billiton Nickel West PTY LTD (formerly Western Mining Corporation Resources Ltd)	80	100	200	100	238	100	312	100	241	100	269	100	215	100	1,555	700	855	1,555	700	855
CSIRO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Curtin University of Technology	100	100	100	100	100	100	100	100	110	100	100	100	100	100	710	700	10	710	700	10
Newmont Australia Ltd	105	105	111	105	105	105	105	105	105	105	131	105	123	105	785	735	50	785	735	50
Technological Resources Pty Ltd	0	350	409	350	264	350	568	350	131	350	538	350	440	350	2,350	2,450	-100	2,350	2,450	-100
The University of Queensland	75	75	75	75	85	75	85	75	95	75	80	75	75	75	570	525	45	570	525	45
University of Sydney	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xstrata Queensland Limited	0	155	240	155	171	155	73	155	23	155	53	155	29	155	589	1,085	-496	589	1,085	-496
Total cash from core participants	457	1,335	1,742	1,335	1,304	1,335	1,741	1,335	1,182	1,335	1,705	1,335	1,373	1,335	9,504	9,345	159	9,504	9,345	159
Supporting participants																				
Ausmelt	0	20	0	20	0	20	5	20	0	20	0	20	0	20	5	140	-135	5	140	-135
Central TAFE	105	50	0	50	0	50	155	50	0	50	0	50	0	50	260	350	-90	260	350	-90
Delta EMD Australia Pty Limited	0	20	0	20	0	20	0	20	0	20	0	20	0	20	0	140	-140	0	140	-140
Environment Australia	20	20	20	20	20	20	20	20	20	20	20	20	20	20	140	140	0	140	140	0
Gladstone Area Industry Network	20	20	16	20	18	20	18	20	7	20	13	20	0	20	92	140	-48	92	140	-48
Hatch Associates Pty Ltd	20	20	20	20	30	20	30	20	65	20	65	20	56	20	286	140	146	286	140	146
Kwinana Industry Council	20	20	20	20	20	20	30	20	40	20	115	20	70	20	315	140	175	315	140	175
Minerals Council of Australia	20	20	20	20	20	20	20	20	20	20	20	20	20	20	140	140	0	140	140	0
NSW Minerals Council Limited	20	20	20	20	0	20	0	20	0	20	0	20	0	20	40	140	-100	40	140	-100
Onesteel Limited	5	75	49	75	0	75	107	75	161	75	246	75	5	75	573	525	48	573	525	48
Other industry participants	0	331	50	662	50	1,003	418	1,254	695	1,254	503	1,254	179	1,264	1,895	7,022	-5,127	1,895	7,022	-5,127
ROCLA INDUSTRIES PTY LIMITED	50	50	0	50	50	50	50	50	100	50	0	50	100	50	350	350	0	350	350	0
Tesla Technologies Pty Ltd	0	20	0	20	0	20	0	20	0	20	0	20	0	20	0	140	-140	0	140	-140
URS Australia Pty Ltd	20	20	0	20	20	20	20	20	0	20	20	20	40	20	120	140	-20	120	140	-20
WA State Industry and Technology	0	345	330	345	0	345	330	0	330	0	0	0	0	0	990	1,035	-45	990	1,035	-45
Total cash from supporting participants	300	1,051	545	1,382	228	1,723	1,203	1,629	1,438	1,629	1,002	1,629	490	1,639	5,206	10,682	-5,476	5,206	10,682	-5,476
Other cash																				
Non-participants	1	0	777	0	651	0	479	0	365	0	751	0	570	0	3,594	0	3,594	3,594	0	3,594
External grants	0	0	0	50	0	50	0	50	0	50	0	50	0	50	0	300	-300	0	300	-300
Contract research	0	500	0	600	20	700	5	800	77	1,300	32	1,700	279	2,100	413	7,700	-7,287	413	7,700	-7,287
Commercialisation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Education	0	50	0	50	0	75	0	100	0	100	0	100	0	100	0	575	-575	0	575	-575
Interest	15	0	106	0	135	0	215	0	293	0	235	0	196	0	1,195	0	1,195	1,195	0	1,195
New from existing starting cash	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total other cash	16	550	883	700	806	825	699	950	735	1,450	1,018	1,850	1,045	2,250	5,202	8,575	-3,373	5,202	8,575	-3,373
CRC grant																				
Total grant	1,500	1,500	2,800	2,800	3,000	3,000	3,500	3,500	3,500	3,500	2,500	2,500	2,000	2,000	18,800	18,800	0	18,800	18,800	0
Grand totals																				
Total CRC cash contribution (T2)	**2,273**	**4,436**	**5,970**	**6,217**	**5,338**	**6,883**	**7,143**	**7,414**	**6,855**	**7,914**	**6,225**	**7,314**	**4,908**	**7,224**	**38,712**	**47,402**	**-8,690**	**38,712**	**47,402**	**-8,690**
Cash carried over from previous year (UB for previous year)			1,118		2,271		2,440		3,611		4,093		4,130		4,130					
(less) Unspent balance (UB)	1,118		2,271		2,440		3,611		4,093		4,130		1,664		1,664					
Total cash expenditure (T3)	**1,155**	**4,436**	**4,817**	**6,217**	**5,169**	**6,883**	**5,972**	**7,414**	**6,373**	**7,914**	**6,188**	**7,314**	**7,374**	**7,224**	**41,178**	**47,402**	**-8,690**	**38,712**	**47,402**	**-8,690**
Allocation of cash expenditure between heads of expenditure																				
Salaries	260	4,356	2,038	4,356	2,040	4,356	2,286	4,356	2,434	4,356	2,510	4,356	2,935	4,356	14,503	30,492	-15,989	14,503	30,492	-15,989
Capital	48	0	41	0	5	0	90	0	55	0	124	0	1	0	364	0	364	364	0	364
Other	847	2,415	2,738	2,415	3,124	2,415	3,596	2,415	3,884	2,415	3,554	2,415	4,438	2,415	22,181	16,905	5,276	22,181	16,905	5,276
Total	1,155	6,771	4,817	6,771	5,169	6,771	5,972	6,771	6,373	6,771	6,188	6,771	7,374	6,771	37,048	47,397	-10,349	37,048	47,397	-10,349

Notes

For 2009-10 financial year

1) Core Participant cash contributions are $159k above budget for the seven years of operation. Supporting Participant cash contributions (excluding "Other Industry Participants") are $349k below budget for the seven years of operation.

2) Refer to the Audit Report and Additional Note - In-kind Industry Funded Activities by Other Industry Participants (UNAUDITED) for information regarding the apparent shortfall between actual and budget cash and in-kind contributions for the line items "Other Industry participants" and "Contract Research".

Financial Information Table 3 – Resources (dollars in $'000)

	Actual														Totals to 2009-10			Totals for 7 years		
	2003-04		2004-05		2005-06		2006-07		2007-08		2008-09		2009-10							
	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Actual	Agr'mt	Diff	Actual/Proj	Agr'mt	Diff
Summary of resources applied to activities of centre																				
Grand total (in-kind) from table 1 (T1)	3,103	6,486	3,736	6,136	4,726	6,136	6,523	6,136	7,282	6,136	7,449	6,136	4,282	6,136	37,101	43,302	-6,201	37,101	43,302	-6,201
Grand total (cash expenditure) from table 2 (T3)	1,155	4,436	4,817	6,217	5,169	6,883	5,972	7,414	6,373	7,914	6,188	7,314	7,374	7,224	37,048	47,402	-10,354	37,048	47,402	-10,354
Total resources applied to activities of centre (T1+T3)	4,258	10,922	8,553	12,353	9,895	13,019	12,495	13,550	13,655	14,050	13,637	13,450	11,656	13,360	74,149	90,704	-16,555	74,149	90,704	-16,555
Allocation of total resources applied to activities of CRC between heads of expenditure																				
Total salaries (cash and in-kind)	1,511	6,448	3,563	6,302	3,971	6,302	4,922	6,302	5,177	6,302	5,247	6,302	4,552	6,302	28,943	44,260	-15,317	28,943	44,260	-15,317
Total capital (cash and in-kind)	48	0	41	0	5	0	109	0	55	0	124	0	1	0	383	0	383	383	0	383
Total other (cash and in-kind)	2,699	6,809	4,949	6,605	5,919	6,605	7,464	6,605	8,423	6,605	8,266	6,605	7,103	6,605	44,823	46,439	-1,616	44,823	46,439	-1,616
Total	4,258	13,257	8,553	12,907	9,895	12,907	12,495	12,907	13,655	12,907	13,637	12,907	11,656	12,907	74,149	90,699	-16,550	74,149	90,699	-16,550

Financial Information Table 4 - Allocation of resources between categories of activity for the 2009-10 financial year (dollars in $'000)

	Resource usage			
	Cash ($'000) [1]	In-kind ($'000)	Contributed staff (FTE) [2]	Cash funded staff (FTE) [2]
Research	5,364	3,764	10.3	12.9
Education	338	185	0.5	0.6
External communications	0	0	0.0	0.0
Commercialisation/Tech. transfer	345	59	0.1	1.6
Administration	1,327	274	0.8	4.4
Total	7,374	4,282	11.7	19.5
	(T3)	(T1)		

[1] Cash from all sources, including CRC program

[2] Full time equivalent staff, excluding students

Notes

For 2009-10 financial year The total cash and in-kind FTE levels are below the Commonwealth Budget/Agreement as a result of the wind-up of research projects.

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Independent auditor's report to the parties to the Cooperative Research Centre for Sustainable Resource Processing, being The Commonwealth of Australia, Alcoa of Australia Limited, Australian Nuclear Science and Technology Organisation, Commonwealth Scientific and Industrial Research Organisation, Curtin University of Technology, Xstrata Queensland Limited, Newmont Australia Ltd, Technological Resources Pty Ltd, University of Queensland and BHP Billiton Nickel West Pty Ltd (the parties)

Report on the financial report

We have audited the financial information of the Cooperative Research Centre for Sustainable Resource Processing for the financial year ended 30 June 2010, as set out in Tables 1, 2,3 and 4 being the tables showing in-kind and cash contributions for each party to the Co-operative, and cash expenditure for the year then ended.

The parties' responsibility for the financial information

The parties are responsible for the preparation and fair presentation of the financial information and have determined that the accounting policies used and described in Note 1 to the financial information are appropriate to meet the requirements of the agreement between the Commonwealth of Australia and the parties to the Cooperative Research Centre for Sustainable Resource Processing (the Agreement). This responsibility includes establishing and maintaining internal control relevant to the preparation and fair presentation of the financial information that is free from material misstatement, whether due to fraud or error; selecting and applying appropriate accounting policies; and making accounting estimates that are reasonable in the circumstances.

Auditor's responsibility

Our responsibility is to express an opinion on the financial information based on our audit. We conducted our audit in accordance with Australian Auditing Standards. These Auditing Standards require that we comply with relevant ethical requirements relating to audit engagements and plan and perform the audit to obtain reasonable assurance whether the financial information is free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial information. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the financial information, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the entity's preparation and fair presentation of the financial information in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the entity's internal control. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of accounting estimates made by the parties, as well as evaluating the overall presentation of the financial information.

We performed the procedures to assess whether in all material respects the financial report presents fairly, in accordance with Australian Accounting Standards (including the Australian Accounting Interpretations) and the requirements of the Agreement, including Clauses 4 (Contributions) and

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5.1, 5.2 and 5.3 (Application of Funding and Contributions), so as to present a view which is consistent with our understanding of the sources of funding and the application of funding of the Co-operative.

The financial information has been prepared for the parties to the Co-operative for the purpose of fulfilling their annual reporting obligations under clause 13.2 of the Agreement and for distribution to the Cooperative Research Centres Program, Department of Industry, Sciences and Resources, representing the Commonwealth of Australia. We disclaim any assumption of responsibility for any reliance on this report or on the financial information to which it relates to any person other than for which is was prepared.

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

Independence

In conducting our audit, we have complied with the independence requirements of the Australian professional accounting bodies.

Audit opinion

In our opinion:

(a) The financial information presented in Tables 1,2,3 and 4 presents fairly, in all material respects, the sources of funding and the application of funding of the Cooperative Research Centre for Sustainable Resource Processing for the year ended 30 June 2010 in accordance with the requirements of the Agreement, and the Australian accounting concepts and Australian Accounting Standards as set out in the basis of accounting described in Note 1 to the financial information;

(b) The financial information presents fairly that contributions, both cash and in-kind, have been expended in accordance with the Budget as specified in Schedule 4 (2002) in accordance with the terms of the Agreement; and

(c) The cash contributions and Commonwealth funding have been paid into and expended from the Co-operatives account and in accordance with the Agreement.

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Matthew Beevers
Partner

Perth

29 October 2010

Note 1: Basis of preparation

The special purpose financial information in Tables 1, 2, 3 and 4 has been prepared in accordance with the requirements of CRC for Sustainable Resource Processing Commonwealth Agreement 1 July 2003 – 30 June 2010.

The financial report has been prepared for the year ended 30 June 2010.

The financial report complies with the application of measurement standards of Australian accounting concepts and applicable accounting standards.

The financial information has been prepared on a cash basis of accounting. The accounting policies have been consistently applied.

Additional Note: In-kind industry funded activities by other industry participants (UNAUDITED)

As per the agreed position with DIISR the apparent shortfall between actual and budget cash and in-kind contributions (totaling $12.714 million over 7 years), including all non-confirmed budget items such as "Other Industry Participants" and "Contract Research" (in Other Cash), is accounted for by the understatement/non-inclusion of contributions of a suite of industry-funded activities with an estimated value of $12.9 million which have been funded external to the CSRP accounts. With this external funding, all anticipated activities have been appropriately resourced.

A number of these outcomes have been funded directly by CSRP Industry Participants and other industry sources, externally to CSRP's accounts. The reasons for this relate to good governance and issues around liabilities, indemnities and other contractual issues that would have been unnecessarily complicated by inserting CSRP as a Party to these contracts.

Examples of these directly funded activities are listed here.

- Seven JKRBT machines have been built at a cost of approx $2M
- Comminution (ore-processing) trials (including high efficiency High Pressure Grinding Roll milling machines) were conducted in South Africa at a cost of $4M. Additional in-kind contributions from other (Australian and International) sponsors are estimated at between $2 to 6M
- Three year geopolymer sewer pipe trials $0.5M
- Three year geopolymer railway sleeper trials $0.5M
- A 500 metre section of highway built with ReSand® $0.5 to 1.0M
- Artificial wetland using mineral processing by-product for nutrient treatment $0.5 to 1.0M
- Bayer (alumina) residue concrete pavement trial #1 $0.2M
- Bayer residue seawall pre-mould trial #1 $0.2M

All of the activities listed above contribute directly to meeting the Objectives of CSRP as stated in our Commonwealth Agreement. They are an integral part of CSRP's work as tangible demonstrations and applications of our outputs and they provide feedback to our researchers to enable the ongoing development and refinement of our research outputs.

Glossary of Terms

Alkaloam® – A fine grained by-product derived from alumina production. Has proved successful as a soil amendment for nutrient deficient, acid soils and can increase the productivity of farmland. Alkaloam® is a registered trade mark of Alcoa.

Aluminosilicate – Compound containing a mixture of sodium, aluminium and silica.

Ball mill – Rotating cylinder partially filled with stone/metal balls which grinds material to the necessary fineness.

Bauxite residue – A by-product consisting primarily of iron oxides and quartz, produced when alumina is extracted from bauxite ore. Also known as "red mud". (source: Alcoa)

Biosolid – A recyclable, primarily organic solid material produced by wastewater treatment (sewerage sludge).

Californian Bearing Ratio – A universally accepted as a measure of soil strength. The ratio of the force required to penetrate a cross section of the soil at a constant rate, to the force required for similar penetration into a standard sample of crushed rock.

Cementitious – Having properties or characteristics suitable for cement production.

Coarse liberation – Separation of the target mineral from the host ore at larger grinding sizes, resulting in less grinding of ore and less energy consumption.

Comminution – Particle size reduction by breaking, crushing or grinding.

Eco-efficiency – Producing more goods and services with less energy and fewer natural resources. Eco-efficient businesses get more value out of their raw materials as well as producing less waste and less pollution.

Exchangeable aluminium – Percentage indicator of the potential aluminium toxicity for sensitive plants. At low pH values, the amount of soluble and exchangeable aluminium increases so that its concentration can become toxic to plants and soil organisms. (source: Food and Agriculture Organisation of the United Nations)

Floatability – The performance of a specific mineral to the flotation process.

Flotation – Process for separating a target mineral from an ore by taking advantage of differences in the physical properties that repel water, selectively separating hydrophobic materials from hydrophilic.

Fly ash – Industrial solid waste by-product produced during the combustion of coal.

Geopolymers – Class of inorganic polymers formed by the reaction between an alkali and an aluminosilicate source. Their amorphous 3D structure and properties make them an ideal substitute for Ordinary Portland Cement. Can be produced from industrial feedstocks including fly ash, mine tailings and bauxite residue.

Gypsum – The common name for a naturally occurring hydrated calcium sulphate ($CaSO_4.2H_2O$). Its main use is in the manufacture of plaster products, cement and agriculture. (source: Department of Primary Industries and Resources SA)

Inorganic by-product – The mineral products left over after processing has recovered the target minerals.

Liberation – Separation of the target mineral from the host ore.

Minor elements – Elements that are present at low levels compared to the target minerals/metals in an ore/concentrate.

Phosphogypsum – A by-product gypsum produced at fertiliser plants during the manufacture of phosphoric acid. It is very high in $CaSO_4$ and has a very small particle size, making it effective for soil conditioning. (source: Manna Enterprises)

Regional synergies – The capture and recovery of one company's previously discarded by-products (materials, energy and water) for reuse by another closely located industry.

ReSand® – Sand-like material recovered from mineral by-products and having a lesser ecological footprint than virgin mined sand. ReSand® is a registered trademark of CSRP.

Run-of-Mine (RoM) – Ore coming directly from the mine, without prior breaking, crushing or grinding etc.

Sustainable development – Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (source: Brundtland Report 1987)

SUStainable OPerations (SUSOP®) – A comprehensive and rigorous mechanism used to incorporate sustainable development principles into the design and operation of industrial processing plants.

Tower mill – Stirred mill used for fine and ultra fine grinding of ore. The feed enters from the top and is reduced by abrasion as it falls down and encounters the grinding media, being agitated and lifted by a rotating screw.

Unified Comminution Model (UCM) – A desktop instant answer simulator that is based on a mechanistic model for all comminution equipment. The models utilise Discrete Element Method outputs and applied breakage testing as their basis.

Virtual Comminution Machine (VCM) – To be used for equipment design, and is run off-line, taking many days per simulation. Uses Discrete Element Method and direct breakage modelling to predict the performance of new equipment, and incorporate subtle design changes.

Abbreviations

AMIRA	Australian Minerals Industries Research Association
ANSTO	Australian Nuclear Science and Technology Organisation
CO2	carbon dioxide
CSIRO	Commonwealth Science and Industry Research Organisation
CSRP	(Cooperative Research) Centre for Sustainable Resource Processing
CUP	Commercialisation and Utilisation Plan
Curtin	Curtin University
DEM	Discrete Element Method
GHG	Greenhouse Gas
HIsmelt	High Intensity Smelting
HPGR	High Pressure Grinding Rolls
JK	Julius Kruttschnitt
JKMRC	Julius Kruttschnitt Mineral Research Centre
JKRBT	Julius Kruttschnitt Rotary Breakage Tester
KIA	Kwinana Industrial Area
KIC	Kwinana Industries Council
OPC	Ordinary Portland Cement
PEPT	Positron Emission Particle Tracking
RIZ	Rockingham Industry Zone
RoM	Run-of-Mine
SD	Sustainable Development
SPH	Smoothed Particle Hydrodynamics
SUSOP®	SUStainable OPerations
TAP	Technical Advisory Panel
TAPWG	Technical Advisory Panel Working Group
UQ	University of Queensland
WWTP	Waste Water Treatment Plant

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For further information on or general enquiries about the Centre for Sustainable Resource Processing:
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* Due to the wind-up of CSRP on 30 June 2010, the Executive contact details are subject to change. Although the Program Leaders will no longer be managing CSRP research programs, their details should remain unchanged.

Cooperative Research Centre for Sustainable Resource Processing

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