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Synthesis and Integrative Research
Final report

Climate change adaptation for Australian minerals industry professionals

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Climate change adaptation for Australian minerals industry professionals

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

Cover image Ensham Mine and Rehabilitation © Tyson Stelzer and Ensham Resources.

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ABSTRACT

Extreme weather events in Australia over recent years have highlighted the costs for Australian mining and mineral processing operations of being under-prepared for adapting to climate risk. For example, the 2010/2011 Queensland floods closed or restricted production of about forty out of Queensland's fifty coal mines costing more than $2 billion in lost production.

This project synthesises case studies, options and skills needed for minerals industry professionals to adapt to climate change in the areas of flood, drought, bushfire and high temperatures and health in a guide called *Adapting to climate risks and extreme weather: a guide for mining and minerals industry professionals*. The guide should be read in conjunction with this final report. The Institute for Sustainable Futures, University of Technology Sydney (UTS) led the development of the guide and worked with a Steering Committee from the Australasian Institute of Mining and Metallurgy's Sustainability Committee and with input from the Health & Safety Committee and individual members, who volunteered their time and experience. This final report describes the research process for developing the guide and reflects on challenges and lessons for adaptation research from the project.

Consultation with mining and mineral processing professionals identified variability in the state awareness, knowledge and preparedness of climate change adaptation in the Australian mining and minerals processing industry. The research found limited information on climate change adaptation for mining and minerals professionals in the public domain, and identified several barriers to having a more precise understanding of the industry's awareness and knowledge at the present time.

While extreme events may have been anticipated in the planning at case-study mines, the extent and costs of damage was not accurately predicted. In areas where flooding and storms are infrequent events, the costs and losses from events that have exceeded the design assumptions of operations have been large, and return to production has taken many months. In areas where such events are routine, it is still possible to under-estimate the effects and the risk posed by an accumulation of small impacts. In both cases, post-flooding impacts have included additional costs for the operations, such as measures to limit or eliminate damage from de-watering processes, and monitoring of local water resources.

The prospect of increased frequency or severity of storm activity in parts of Australia, combined with extended periods of drought and more extended periods of high temperatures, increases the risks of damage from subsequent heavy rainfall and flooding. Success in reducing or managing such risks will require planning and risk mitigation procedures that incorporate heavy rainfall and flood into operational models and increased awareness at sites.

Consultation during this project identified a range of adaptive approaches to planning which build on an established culture of safety and risk assessment in the sector and that can assist Australian mining and mineral processing professionals in responding to the prospect of increased risk from a changing climate.

Further development of capacity for adaptation amongst mining professionals may be dependent upon greater knowledge sharing in the public domain and a more active dialogue with government and communities regarding the importance of climate change adaptation as part of the industry's 'social licence to operate'. Adopting a collaborative approach to recognising the potential implications of extreme weather events would allow industry professionals to focus on planning and delivering adaptation measures to benefit stakeholders and industry.

EXECUTIVE SUMMARY

Objectives, research activities and methods

The three objectives of the project were to:

(i) assess the level of readiness for climate change adaptation risks in the minerals industry;

(ii) engage AusIMM members (11,000 industry professionals) with the issue and evaluate existing strategies; and

(iii) develop new adaptation pathways for inclusion in a guide for climate change adaptation and planning by minerals industry professionals.

Research activities used to develop the guide included a desktop literature review; a stakeholder consultation workshop; an online survey of end-users and selected interviews, followed by the development of the guide. Despite difficulties associated with discussing climate change dispassionately; this research has, for the first time compiled a range of measures that can assist in developing the capacity of Australian mining and minerals professionals to adapt to climate change. Feedback on the draft guide identified additional adaptation options, including the value of adopting 1,000 year planning for tailings dam construction and management.

Results and outputs

The literature review highlighted that, apart from recent work by CSIRO, little explicit focus had been given to climate change adaptation and mining in Australia. Indeed, at the time of the literature review in January 2012, international literature on climate change adaptation aimed specifically at minerals industry professionals – namely the geologists, mining engineers, community & environment professionals who work in the industry – was scarce, although some work in Canada had been undertaken with a specific focus on mining communities

The framing and format for the guide *Adapting to climate risks and extreme weather: a guide for mining and minerals industry professionals*, emerged as a result of close consultation with AusIMM members whose views about climate change are quite divergent. The prospect of significant discord within the organisation has made it difficult to present 'climate change' and 'climate change adaptation' to end users in the manner anticipated and an operational point of consensus was established around 'extreme weather'.

Using the focus of planning, preparing and managing sites under extreme weather conditions, it has been possible to document considerable variety in the experience and knowledge of those who provided feedback to the AusIMM member survey. Of members participating in the survey, 12% had no professional experience of extreme weather events. Slightly more than a third (38%) had analysed risks associated with extreme weather events, and more than half had experience of planning for these events.

Those with experience of planning, preparing and managing extreme weather indicated that experience itself was very important, as well as knowledge and skills in the areas of risk assessment, risk management and the complex interaction of landforms and hydrology, site structures, seasonal weather patterns and longer climatic cycles (e.g. El Niño and La Niña). Responses to the members' survey and follow up interviews indicated that local and historical knowledge of specific sites (as opposed to a more general knowledge of factors involved in extreme weather events) was also valuable.

Responses to questions about the impact of new legislation indicated that survey respondents did not see significant changes to their own roles from this aspect of climate change adaptation.

Survey and interviw responses confirmed the value of case studies in engaging the end-user audience, and the importance of flooding events create in revealing vulnerabilities at sites and for local communities. The effects of low rainfall (drought) and higher temperatures over longer periods (particularly during drought periods) were less prominent in the responses of AusIMM participants. Nonetheless, capacity to adapt to drought conditions has been demonstrated by many operations, and approaches taken to managing these types of weather events provide some guidance for developing greater capacity in other areas of adaptation.

In the absence of explicitly 'climate change'-related or 'climate change adaptation'-related material, the review focussed on identifying measures being taken to address key elements identified by Loechel et al (2010), namely water and energy efficiency, environmental and community impacts, as well as mine planning and design. Synthesis of existing materials on water efficiency, flooding and storm impacts, and issues associated with extended periods of higher temperatures has provided a foundation for creating an informed, sector-wide response to extreme weather events. Survey and interviews have also provided insights into the experience, knowledge and skills that are presently available from professionals with decades of experience at particular sites.

Key findings from the guide Adapting to climate risks and extreme weather: a guide for mining and minerals industry professionals

Business case for planning and preparation

Reference to specific climate change adaptation planning by mining companies is not widely reported in publicly available documents. However, the industry has an established culture of risk planning and preparation. Given the costs of high profile mine disasters including those from floods or bushfires – there is a strong case for using adaptive management with a focus on a changing climate within broader risk planning processes.

Flooding and storms

As 2010/2011 flooding and storm events in Queensland, NSW, and WA have shown, the impact of extreme weather events on operations and distribution of minerals has been enormous, as well as for local and wider communities. Accordingly, the risk assessment and management processes of operations are a key concern of local, state and federal authorities, as well as for insurers. Impacts were exacerbated leading up to the floods because planning had often been focused on coping with too little water (drought) rather than too much.

Key impacts included closed and damaged infrastructure from the storms (including coastal surges affecting port facilities) and an inability to adequately dispose of large volumes of polluted mine water arising from the storms in inland locations – including from abandoned mines. Adaptation options include retrofitting levee banks to withstand 1-in-1,000 year floods and designing tailings dams to last for 1,000 years.

Drought

Water scarcity from drought is also problematic, with both direct and indirect effects. A lack of water can have a direct impact on operations and recycling facilities may be needed. For mines connected to the electricity grid, a lack of water near power generators can also affect energy security and prices. Importantly, in times of water shortages ‘social licence’ can be compromised where the mine is competing for water with farmers or the local community.

A key strategy to reduce water use (and environmental impact) is the implementation of thickened or dry tailings disposal.

Other useful adaptation options include the use of a catchment focus to inform site water balance models. This allows plans for operations across a range of water availability conditions, efficiency and recycling technologies, and catchment water management plans (regarding sharing arrangements in drought) involving communities and other stakeholders. This also needs to include clear procedures for discharges which can have higher concentrations of pollutants where water is recycled.

Higher temperatures, health and safety

The potential for higher temperatures in parts of Australia in future decades has several implications, including increased worker stress (both on site and in residential location where Fly-In-Fly-Out or Drive-In-Drive-Out), fatigue and potential for accidents. Mosquito-borne diseases may become prevalent in greater parts of Australia requiring greater focus on preventative management strategies. Bushfires are also an ongoing threat from high temperatures and winds in vulnerable areas – for mines themselves and in electricity supply areas.

Adaptation options include improved management plans for managing health, safety, fatigue and fire risk as have been implemented in Australia and overseas.

Conclusions and recommendations for further research

As recent flooding and storm events in Queensland, NSW, and WA have shown, the impact of extreme weather events on operations and distribution of minerals has been enormous, as well as for local and wider communities. Accordingly, the risk assessment and management processes of operations are a key concern of local, state and federal authorities, as well as for insurers.

Changes to historical climatic conditions are likely to increase the efforts required to protect physical assets, worker and community health and safety, and improve the environmental performance of operations before, during, and after extreme weather events. Mining and mineral professionals have key roles to play in meeting the changing expectations of stakeholders by ensuring that operational responses to these events are well grounded in leading practice and current information.

In concluding this work, there are three main areas that merit further investigation.

Firstly, divergent views within the AusIMM may be a matter of experience, disciplinary-alignment, or a reflection of an absence of consensus within one or more key member groups. While limited in size, interviews with very experienced survey respondents revealed a range of views about the relationship of extreme weather events and climate change. Further investigation of the relationship between experience, age, professional environment, and views being expressed in the public domain may be very useful in understanding the diversity within the organisation, and for resolving these tensions. Exploring the positioning of different industry stakeholders (mining companies, financiers, insurers, shareholders, universities or other training providers and research organisations, peers and fellow professionals, media, state/federal government departments) may also be valuable.

A second area to evaluate is the role that the creation of a ‘non-competitive environment’ for knowledge sharing, might play in improving adaptive capacity. A collaborative approach such as the one taken to abandoned mines in Canada (an agreement between Canadian government and the mining industry – see NOAMI 2009) may help to progress the development of climate change adaptation on an industry scale. It may be possible to use a similar approach to creating an information hub for ‘best practice adaptation’ and ultimately achieve agreement regarding an appropriate benchmark.

Finally, building on interest in weather forecasting/meteorology, risk assessment and management, it would be useful to investigate how remote operations technology in mining will affect capacity to manage extreme weather events such as flooding, storms, higher temperatures and bushfires.

1. OBJECTIVES OF THE RESEARCH

This project arose from a joint submission between the Institute for Sustainable Futures at UTS which conducts industry-relevant research, and The Australasian Institute of Mining and Metallurgy (AusIMM) which represents more than 11,000 professionals working in the industry.

The foundation of the project objectives built upon one of the few studies that explicitly focussed on major challenges for climate change in the minerals industry (Loechel et al, 2010), which noted five main areas of concern. These ranged from use of scarce resources (water/energy), through impacts on environment and community, to the variability of engagement with mine planning and design across different mining and industry services. A critical factor affecting vulnerability to climate change in this study was identified as 'access to information and knowledge' (Loechel et al, 2010).

For this reason, the objectives of the project were to:

- Assess the level of readiness for climate change adaptation risks in the minerals industry including current knowledge of risks, skill level of professionals, suitability of business planning practices;
- Engage 11,000 AusIMM members with the issue and develop adaptation measures and pathways; and
- Evaluate existing strategies and develop new adaptation pathways for inclusion in 'Best Practice Guidelines for Climate Change Adaptation and Planning by Minerals Industry Professionals' (the term Best Practice was removed from the final title as established best practice is still emerging). The final title for the guide is *Adapting to climate risks and extreme weather: a guide for mining and minerals industry professionals*.

The involvement of AusIMM has been invaluable, both for the insights that the collaboration has generated with respect to the variety of responses to the issues of climate change and climate change adaptation, and for ensuring that the project was able to involve well-placed end users. This will enable the outcomes of the project to be widely distributed within the industry.

2. RESEARCH ACTIVITIES AND METHODS

This section outlines the course of the project as planned in the proposal and as the project developed with input from research findings, the steering committee and end users. High-level summaries of the methods and outcomes from the proposed and actual project have been provided in the Appendices.

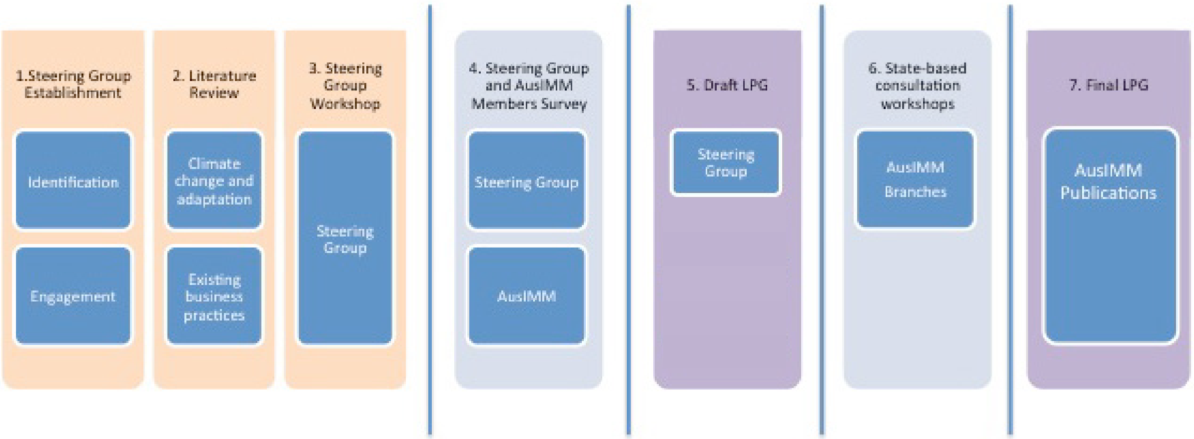

Figure 1: Process diagram of project proposal

2.1 Proposed Approach and methods

The originally proposed approach and methods for the project were:

- Review, synthesis and communication of existing research on climate change adaptation (industry case studies on business planning practices and a literature review on risks and adaptation strategies) as a means of engaging industry stakeholders;
- Conduct of stakeholder workshops and online survey that assist minerals professionals to:
    - Assess and prioritise suitable pathways based on best-practice approaches to climate change adaptation;
    - Develop new options where suitable options do not currently exist, or where international examples are considered inappropriate to the Australian context; and
- Use outcomes from research and stakeholder engagement phases to inform the development and dissemination of the guide for best practice adaptation to climate change.

Figure 1 outlines the process anticipated in the project proposal. It shows a foundation phase (1-3) which includes establishing a steering committee and communication plan for engagement (1), together with a literature review of climate change adaptation and mining globally to inform the research gaps to be targeted in the project and the contents of the guide (2). The literature review is then presented to the steering group in (3) to set broad direction for the remainder of the guide development and engagement. Phases 4 and 6 were proposed as consultation before and after the development of the draft guide (phase 5) and phase 7 incorporating finalisation and launch of the guide.

2.2 Changes to project approach and methodology

Changes to the approach taken to developing the guide occurred between stages 2 and 3 of figure 1. During preparations for the first steering groups workshop, it became apparent that there was ambivalence within AusIMM membership regarding the use of the term ‘climate change’, as this is viewed by a number of members as synonymous with ‘anthropogenic climate change’. On the advice of the steering committee, it was decided that a change in approach would be required to maintain rapport with the end-user group targeted by the project.

To this end, the research undertaken in stages 4-7 of the original project plan has emphasised:

- Understanding existing capacity, and gaps in knowledge or expertise, about several types of extreme weather that are likely to increase in frequency or severity;
- Consultation processes and survey work around these events and issues; and
- Strategically framed information to support the ongoing development of leading practice in climate change adaptation in mining and mineral processing.

The research team, and the steering group established to guide the project, consider that the change in emphasis has allowed the project to meet the goals of engaging end users with adaptation while recognising the present division within the professional membership of AusIMM. Importantly, this recognition has played a key role in facilitating discussion of the needs and experience of industry professionals. Further discussion of the impacts of this change in emphasis is provided in later sections.

As shown in figure 1, the proposed project process anticipated opportunities to engage state branches in a consultation process on the draft of the leading-practice guidance. However, several factors influenced the substitution of this phase with further research and targeted stakeholder feedback. Consequently, the project team changed its approach to getting feedback on the draft guide. These changes have been outlined in figure 2, and a brief overview of how the project was conducted follows.

2.3 Project Implementation Process

Figure 2 below provides an outline of the amended process that was taken in the course of the research, and this process is explained in more detail in the following sub-sections.

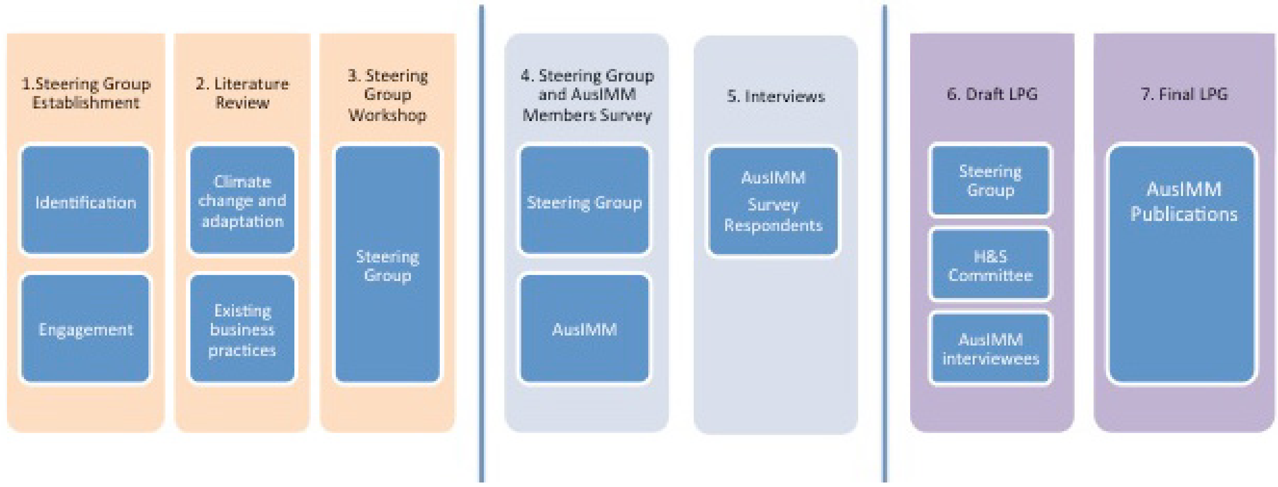

Figure 2: Process diagram of project implementation

As shown in figure 2, project implementation involved three distinct phases of work and stakeholder engagement and review of the draft leading-practice guide was strengthened in the above diagram. It should be noted that different stakeholders provided feedback at various points throughout the process. Table 1 (below) provides a brief outline of project activities and type (stakeholder engagement and/or research).

Table 1: Overview of project activities and timeline

	Activity	Dates
1	**Establishment of Steering Group and Communication Plan:** a steering group comprised members from the Global Greenhouse and Energy panel within the Sustainability Committee of the Australasian Institute of Mining and Metallurgy, plus Barton Loechel from CSIRO.	Dec 2011 – Jan 2012
2	**Literature Review:** A desktop literature review of existing information on climate change adaptation in business, with particular attention paid to information, strategies, tools and processes being used by natural resource based industries.	Jan to Feb 2013
3	**Steering Committee Workshop:** Steering Committee members met at the University of Queensland for a face-to-face meeting of the AusIMM Sustainability Committee, and were presented with the implications of climate change related legislation (Clean Energy Futures), and the outcomes of the NCCARF literature review on climate change adaptation. Discussion points raised at the workshop were noted for further exploration.	Feb 2013
4	**Online Members Survey:** Consultation involved an online survey (using Survey Monkey) to pose a series of questions about the roles, affiliation, seniority, and experience of members regarding extreme weather events as well as desirable formats for the presentation of information (fact sheets, guidebook, website etc.).	Mar- Apr 2013
5	**Additional Interviews with survey respondents:** Four detailed interviews with industry professionals (not originally planned in the proposal) were undertaken with a sub-set of the survey respondents who expressed their interest in making further contributions to the development of the leading-practice guide.	May 2013
6	**Draft Guide:** A guide was developed using case-study materials identified in the literature review and via the Steering Committee workshop. Early drafts were circulated to the steering committee, NCCARF, and AusIMM for feedback. Comments from these stakeholders were then incorporated into a consultation draft.	March 2013 – October 2013
7	**Final Guide:** The final guide is published as a separate document by NCCARF, and provided to the AusIMM for desktop publishing and distribution. Early feedback from stakeholders indicates that with the addition of two case studies on rehabilitation impacts of extreme weather events, this guidance will be a very useful first step in opening up further discussion of leading-practice adaptation to changing climate.	November 2012- March 2013

The final guide *Adapting to climate risks and extreme weather: a guide for mining and minerals industry professionals* represents a second output from the project. The material will be published by NCCARF and will also be developed as an downloadable ‘handbook’ style document by the AusIMM.

Summaries of the results for each phase have been provided in the Appendices. The outcomes of the project, as implemented, are described in further detail in the following section, including how each affected the development of the guide.

3. RESULTS AND OUTPUTS

Previous sections have documented the approach taken to the research. This section outlines the project activity outcomes and key results from these activities, in terms of their contribution to objectives of the project. Summaries of results from these activities are provided in the Appendices.

3.1 Assessment of awareness, knowledge and adaptation experience

In line with the first objective to 'Assess the level of readiness for climate change adaptation risks in the minerals industry;' the project has evaluated the material available for professionals in the mining and mineral processing industry, and consulted with professionals regarding their awareness, knowledge and experience of extreme weather events.

Research activities that have provided information about this aspect of the project are the literature review, and engagement with AusIMM members (workshop, survey, interviews, and feedback processes).

Jan – Feb 2012: Literature review

The desktop literature review posed a series of key questions about the nature of the risks, and the drivers for adaptation. It appeared that there was little existing literature for this industry that explicitly addressed climate change adaptation with respect to mining and mineral processing operations in Australia.

The majority of information identified in the initial review related to flooding and storms, energy and water efficiency, and drought. Climate change adaptation information in the public domain was:

- Either generic or highly technical;
- Focussed upon understanding or interpreting complex meteorological and climatic phenomena with little application to specific professional groups within industries, other than agriculture; and
- Framed using Intergovernmental Panel on Climate Change (IPCC) global scenarios and projections.

Importantly, definitions for important concepts in climate change adaptation were different (in some cases substantially) across a range of different resources. There are a number of different definitions for climate change adaptation. A broad definition was adopted as a basis for opening a discussion of climate change adaptation initiatives and measures that could be adopted by the mining and mineral processing industry. With this aim in mind, 'climate change adaptation' was defined as: **any adjustment made by individuals, governments or organisations to expected or actual changes in climatic conditions**. A range of other terms has also been provided as part of the literature review, in a list of 'useful terms'.

In the absence of explicit climate change-related or climate change adaptation-related material, the review focussed on identifying measures being taken to address key elements identified by Loechel et al (2010), namely water and energy efficiency, environmental and community impacts, as well as mine planning and design.

The literature review revealed that existing leading-practice manuals for the mining sector made little or no reference to 'climate change' or 'climate change adaptation'. Analysis of reports by insurers and other industry stakeholders, regarding implications for knowledge and skills of mining and mineral processing professionals, indicated that there may be significant benefit in approaching the guide as an extension of existing competencies in risk assessment, risk management and health and safety practices. This approach has been adopted.

Identifying useful case studies was seen by the steering committee as a key element to engaging the intended audience. However, due to the commercial-in-confidence nature of mining corporations' risk management and planning manuals, it is difficult to find information about relevant events or practices. Where these have been found, it has been due to either the existence of a program aimed at opening forums for knowledge exchange in industry (the Australian Government's Energy Efficiency Office), or the public nature of disastrous failure of mining operation systems, which have resulted in coverage by media, proceedings by government or courts. For this reason, some of the most relevant material for Australia is quite negative.

Inexplicit, but still relevant, examples of climate adaptation were found in actions being taken to assess or respond to the risks of higher temperatures, lower rainfall, increasing frequency and or severity of 'one-in one-hundred year' weather events (Nelson and Schuchard, 2011). Climate change adaptation can also be seen in planning for new infrastructure that seeks to reduce or eliminate the impact of flooding events, and in retrofitting initiatives that relocate or reinforce existing infrastructure against such events (AGIC, 2011). Climate change adaptation can also be seen in actions that reduce the energy intensity of operations or change the energy mix to lower the emissions of carbon dioxide from routine operations (Loechel et al., 2010; Nelson and Schuchard, 2011).

Early research also addressed the style of existing guidance for this end-user group. The leading-practice handbooks (DRET 2002- 2012) were identified as a potential template for the structure and format of the final guide. These resources have been well received in Australia, and internationally, and consistency with this series might create a useful link with the leading-practice handbook series.

Although it was initially thought that the guide should include information about legislative and regulatory change, this area has remained somewhat fluid, during the process of developing the guide. This information may be best supplied in a format (such as a standalone fact sheet) that is more suitable for frequent revision.

The draft literature review was submitted to NCCARF as part of ongoing progress reporting in June 2012.

Feb 2012: Steering Group Workshop

At the steering group workshop, effectively the first of the project stakeholder engagement, it became clear that there were potentially serious conflicts that could be generated by the original approach taken to the research, and the framing of the content in the guide as 'climate change' adaptation. Feedback provided at this workshop resulted in several changes to the proposed guide, including changes to the title and to the framing of the ongoing research as adaptation to a variety of extreme weather events. Other key points that influence the guide include:

- Additional support for the value of a case-study approach, such as that taken by the Department of Resources, Energy and Tourism (DRET) Leading-practice handbooks on sustainable mining, and the need for additional case-study material;
- The potential utility of framing climate change using the term 'extreme weather' as just another risk to be accounted for under existing risk assessment and management practices;
- Recommendations for an extreme weather event based structure with case studies that demonstrate impact and implications, rather than a structure based on the roles of mining professionals that might be present at a given stage of

mine life cycle;
- A section on drought; and
- The need to engage directly with ‘how to’ adapt, rather than ‘why’, to avoid conflict.

Input from the steering committee also informed the development of the online members’ survey. Key points included:

- The need for an investigative baseline approach – namely, what is known and how is it known?
- The need to confirm, by survey, the most useful format for the guide.

Mar – Apr 2012: Online members’ survey

After a preliminary survey with the steering group to establish a suitable tone and strategic questioning approach, an online survey open to the entire AusIMM membership was advertised by email in late March 2012. The survey received responses from 47 persons by the survey closing date in April 2012. The feedback provided by this survey:

- Confirmed the importance of the following points in assessing, planning or managing extreme weather events:
    - Experience with extreme weather events
    - Interest in weather forecasting/meteorology
    - Risk assessment
    - Risk management
    - Local knowledge
    - Historical data
    - Communication
    - Hydrology
    - Preparation
    - Engineering experience;
- Supported the value of case studies to illustrate impact and implications;
- Focussed, in the majority, on flooding and storm-type events;
- Showed little in the way of antagonism towards the notion of ‘adaptation’ in the context of extreme weather events; and
- Confirmed the value of a ‘handbook’ or fact sheet style format for information.

Survey responses also indicated that the respondents felt that, at the time of the survey, there would be little or no change to their present role with respect to new legislation.

May 2012: Interviews

Four detailed interviews with industry professionals (not planned in the original proposal) were undertaken with survey respondents who expressed their interest in making further contributions to the development of the leading-practice guide. The feedback provided by interviews indicated mining and mineral professionals with experience of extreme weather events had very different experiences of extreme weather, different positions about the significance of these events, and different perspectives about how the events should be understood as risks to operations.

Other key points with respect to the guide:

- Initial decisions about infrastructure are often made without the benefit of serious investigations of landforms, hydrology, or local weather, and these decisions make a difference to what can be done later ;

- People with decades of experience in mining are increasingly rare with employment at a particular site being of comparatively short duration;
- Opportunities to transfer information between people with experience and those without are also becoming rarer due to changes in workforce management;
- Adaptation options cross roles and mine life stages, and make communication of risks and impacts over time important; and
- Much higher levels of engagement with meteorological information is required if costly impacts are to be avoided.

Interview feedback has been incorporated into the consultation draft of the guide, and has also been used as the basis of an article for the AusIMM Bulletin on extreme weather promoted as an excerpt from the guide. This article appeared in the February 2013 AusIMM Bulletin.

Mar 2012 – Oct 2012: Draft Guide Development

A draft guide was developed using case-study materials identified in the literature review and via the Steering Committee workshop.

Examples used in case studies have been either adapted from existing materials on areas related to climate change and climate change adaptation (energy efficiency, water efficiency, health and safety issues related to high temperatures, and emergency planning), or pieced together from a range of public sources (including media reports, annual reports, proceedings or rulings of courts, media releases, and conditions of consent).

Drafts of the guide have been submitted to NCCARF as part of ongoing progress reporting. The research team also held discussions with NCCARF project contacts (David George; David Rissik) and with Wayne Robins (AusIMM) regarding the approach to the guide. The feedback provided resulted in further testing of end users receptivity to alternative titles for the guide, and presentation of information about IPCC and CSIRO projections.

The research team also communicated and exchanged information with other researchers working on related projects, including projects undertaken on regional approaches to mining adaptation (Vigya Sharma, University of Queensland) and on adaptation in Small to Medium Enterprises (SME) and local government (Pierre Mukheibir, Natasha Kuruppu, ISF). The feedback provided by these informants has confirmed that the framing of adaptation to extreme weather events is one that has been useful in other projects dealing with different sectors (SMEs).

Following input from discussions with the AusIMM, it was decided that feedback workshops with state-based branches would be superseded with more extensive consultation with other key AusIMM members, in particular the Health and Safety committee – an active group within the AusIMM and an area in which there is a history of significant change achieved. Comments from all of these stakeholders were then incorporated into a consultation draft and circulated with a feedback template.

A review from selected members of the steering committee and additional reviews were obtained from members of the AusIMM Sustainability Committee (who didn't serve on the Global Greenhouse and Energy panel which comprised the bulk of the Steering Committee for the project), an additional CSIRO researcher (Jane Hodgkinson) suggested by NCCARF, CSIRO's Barton Loechel who serves on the Steering Committee, professionals interviewed during the main consultation phase of the project, and the AusIMM Health and Safety committee.

The feedback provided by reviewers of the consultation draft included the following suggestions:

- Numbered case studies for ease of reference;
- Incorporation of more general principles for climate change adaptation;
- Addition of more references to a range of scientific studies held by CSIRO,
- Clearer links between case studies and adaptation options; and
- Use of risk management systems that are already accepted within the industry as a way of engaging the audience with new risks.

Notable again, in this feedback, is the divergence in acceptance of the importance of 'climate change' as a framing element of the discussion of adaptation to extreme weather events. Several examples of this divergence can be seen in the responses to the appropriateness of the guide title. Table 2 provides a summary of responses to a direct question regarding the title.

Table 2: Illustration of importance of project framing for end-user engagement reflected in title choices

Reviewer	Preferred choice	Reason
CSIRO 1	Adapting to a changing climate: leading-practice guidelines for mining professionals	Concise and cuts to the chase
CSIRO 2	Leading-Practice Guidelines: Planning and Preparing for Extreme Weather Events	… I think the title would invite a wider audience and include anyone within or outside of the mining chain to explore the relevance of this to them
AusIMM 1	Prefer one that includes adapting to climate change	None given
AusIMM 2	"One issue that you might want to think about in terms of the title is that the use of the phrase 'Leading-Practice Guide' has some specific meaning to H&S Committee members… "	"….it is used in other contexts for much more detailed and specific guidelines on hazard identification, risk assessment and risk control implementation/management….If you use that phrase in the title of this document it may lead some people to expect much more detailed guidance (almost a 'how to' style guide) than is the intent/purpose for this particular document."
AusIMM 3	"Leading-Practice Guidelines: Planning and Preparing for Extreme Weather Events. I think it is really the consequences of the weather events (rather than cause of these events) that is of most interest to members."	"I think the title should avoid the term climate change (given the connotations and debate that that can produce with some members in the AusIMM) and therefore should be alternate title."

A further example of the type of response anticipated by the final reviewer (AusIMM 3 in table 2) comes from an interviewee from project phase 5 (see table 1), who was provided with the consultation draft for comment. This response indicates a very high sensitivity to what the research team believed was a very careful handling of the relationship between climate change and extreme weather events:

"I am troubled by the concept of Extreme Weather and the link to climate change…. Given that my thoughts align with Ian Plimer on the concepts of climate change I would prefer not to be associated with a document that is peddling concepts that use science badly."

Nov 2012 – Mar 2013: Final Guide Development

Reviewer comments (peer and stakeholder groups) have been addressed in the final draft of the guide. The feedback provided has resulted in several changes to the proposed guide, including further changes to the title. Other key points of feedback that influenced the direction of the document include:

- Foregrounding of long-term trend information previously included in section 6 within relevant sections (i.e. sea-level rise has been included in the Flooding and Storms section);
- Consolidation of additional resources as a separate section; and
- Consolidation of a section on Bushfire (suggested at steering group workshop) within section on High Temperatures.

Reviewer interest in having more detailed attention focussed on water management under different extreme weather conditions, and at different points in the mine life cycle have been addressed through the commissioning of additional features on tailings management, abandoned mines, and sites affected by alternating extremes of drought and wet weather.

Engage 11,000 AusIMM members with the issue and develop adaptation measures and pathways

As noted in this report, stakeholder survey data and interviews have provided very valuable information regarding the current attitudes of AusIMM members towards climate change and climate change adaptation, as well as a range of different experiences that mining and mineral professionals have of extreme weather events. This work has provided the research team with useful foundations for developing appropriately framed information on how mining and mineral professionals have or should plan and prepare for extreme weather events in a range of settings. The research team's engagement with the AusIMM steering committee, AusIMM management, and the AusIMM health and safety committee has also been helpful in developing that organisation's understanding of its capacity to be involved in research projects, and to negotiate the tensions that this can generate.

AusIMM will be publishing a version of the guide in the form of a handbook that can be downloaded from its website.

Evaluate existing strategies and develop new adaptation pathways for inclusion in the *Guide for Climate Change Adaptation and Planning by Minerals Industry Professionals*

The amount of existing literature that directly addresses climate change adaptation in the mining and mineral processing industry is comparatively scarce, with an even smaller subset being immediately applicable to the Australian context.

As noted previously under objective 1, there is an absence of a significant body of specific information for mining and mineral professionals. Therefore, examples of adaptation to a range of issues that have been identified as more likely to manifest under climate change projections and long-term trends have been evaluated for their potential as guidance.

The remainder of this section represents summary information from the guide *Adapting to climate risks and extreme weather: a guide for mining and minerals industry* *professionals* that has been published as a companion document by NCCARF. This information has also been published in slightly altered form as an electronic handbook by the AusIMM.

3.2 Summary of information (excerpts from Guide)

Extreme weather events have often shown the full force that rain and wind can bring to bear on human settlements and infrastructure. Yet even slight changes to historical climate conditions can increase the cumulative impact of these events. The extent of damage is often underestimated, as shown by the planning and preparation ahead of the 2010-2011 Queensland floods. Costs and losses have been large, and in many cases, the return to full production for mine sites has taken many months.

Facilities based inland and on the coast will be affected in different ways. For coastal facilities, if a storm occurs during a 'king tide,' then the potential for flooding is going to be much higher when the tide is low. Similarly, the temperature of the water will have an impact on the way a storm travels, and the force or speed of the wind. The actual impact on coastal facilities will be dependent on how these factors interact at the time, but also on the shape of the sea bed and land forms (CSIRO 2007) in the area. Operations in the near vicinity of rivers, or in flood plains where 'ephemeral creek lines' run through or near mining operations, are also likely to be affected by flooding and storm events. These events may be less complex to predict, but in areas such as the north of Australia, there are significant seasonal differences that will mean the impacts of events will be different at different times of the year. For these reasons, planning and preparation for flooding and storms needs to be well informed by a good understanding of local conditions and variability.

Risks and impacts from flooding and storms can be direct, indirect (or a combination of both), and an overview of impact types, is given below.

Direct impacts from flooding and storms can occur when flooding or storms damage equipment, infrastructure, and personnel. Damage to personnel and equipment can take place when:

- Storage and accommodation are built in areas where water will build up, or travel through at high speeds, under storm or flooding conditions;
- The design specification of water storage on site is lower than is required, resulting in the mobilisation of additional water, contaminants and physical hazards from dislodged and damaged structures, all of which can threaten the health and safety of mine staff and nearby communities;
- Filling of mine pits hampering operations and creating a contaminated water legacy.
- Failure of tailings dams such as occurred in Baia Mare, Romania from heavy rain and melting snow (which was 50% owned by the Australian company Esmeralda Exploration); and
- Progressive rehabilitation measures are affected, resulting in breaches of regulation and setbacks to long-term closure planning programs.

It is also possible for there to be a direct impact to mining operations when flooding and storms affect major cities or other population centres where Fly-in-Fly-out or Drive-in-Drive-out work forces are living between their rostered work days.

Indirect impacts from flooding and storms also need to be considered. Indirect impacts can arise as a consequence of direct impacts and post-flooding impacts. These may include:

- Lost productivity due to damaged or unavailable equipment;
- Loss of reputation based on perceptions that preparation or management systems were inadequate;
- Lost business due to reduced production; and

- Increased costs for ongoing operations in the aftermath of flooding (measures to limit or eliminate damage from de-watering processes, and monitoring of local water resources).

The 2010-11 Queensland floods have also illustrated the complexities of managing water under different conditions. While many mining operations in Australia put a great deal of effort and expense into ensuring that there is enough water for their needs using dams and other types of storage [with accommodating drought conditions as top of mind], having a maximum capacity of water stored onsite at all times can increase the risks to the site and to communities or businesses downstream, when drought turns to flood (Queensland Floods Commission of Inquiry 2012).

While extreme events may have been anticipated in planning at case-study mines, the extent and costs of damage was not accurately predicted. In areas where flooding and storms are infrequent events, the costs and losses from events that have exceeded the design assumptions of operations have been large, and return to production has taken many months. In areas where such events are routine, it is still possible to underestimate the effects and the risk posed by an accumulation of small impacts. In both cases, post-flooding impacts have included additional costs for the operations, such as measures to limit or eliminate damage from de-watering processes, and monitoring of local water resources.

The prospect of increased frequency or severity of storm activity in parts of Australia, combined with extended periods of drought and more extended periods of high temperatures, increases the risks of damage from heavy rainfall and flooding. Success in reducing or eliminating such risks will require damage and risk mitigation procedures that incorporate heavy rainfall and flood into operational models. In some areas, the frequency of flooding and storms will have a large impact on the type of actions required to reduce and eliminate risks.

Impacts & Adaptation Options

Identifying hazards presented by the interaction of daily, seasonal and once-in-a-lifetime events requires a good understanding of site positioning, local flooding history, daily and seasonal weather patterns and long-term trends.

Mining and mineral processing operations can avoid or limit risks and impacts by:

- Modifying existing risk identification processes to incorporate combinations of daily, seasonal and less frequent weather events to ensure that the cumulative impact does not exceed the specifications of key infrastructure;
- Developing or using existing climate models to evaluate potential risks based on local and regional data;
- Implementing measures that will address the risks identified; and
- Monitoring and reviewing the risks, relevant data, and identified measures, on an ongoing basis, to ensure that these are as appropriate as they can be.

Examples of **Modifying existing risk identification processes** include:

- Norsk Hydro incorporates flood risks into standard social and environmental risk assessment (Norsk Hydro 2010; Nelson & Schuchard 2011); and
- Anglo American plans to integrate a ‘climate test’ into its capital- expenditure approval processes (Nelson & Schuchard 2011), and now requires that all operations and projects complete climate change vulnerability assessments to determine whether they are “high-risk sites”. Sites that qualify are then expected to undertake climate change impact assessments” (Anglo American

2010; Nelson & Schuchard 2011). Climate criteria are also being incorporated into a new standard for mergers, acquisitions and divestments (Anglo American 2011).

Examples of **Developing or using existing models to assess likely risks and impacts** include:

- Downscaled general circulation models have been used by Exxaro to assess impacts for both operations and communities where employees are located (Nelson & Schuchard 2011);
- Data on the probability, magnitude, and frequency of extreme weather events at sites has been gathered by Kumba Iron Ore as part of evaluating their cumulative impact on structures (Nelson & Schuchard 2011);
- Changes in temperature and rainfall that are a hazard for Anglo American operations, have been modelled at the site level in order to help create a risk inventory and site-level adaptation strategies (Nelson & Schuchard 2011); and
- Extreme weather was cited as being a potential cause for future 'catastrophe' around mine sites in the Philippines, prompting the Philippines Department of Environment and Natural Resources to prepare a geohazards map that integrates land use planning, land development, disaster risk reduction and climate change adaptation to identify landslide and flood prone mining regions (Loechel et al 2010).

Examples of **implementing measures that increase the capacity of sites, plant, and systems to withstand increases in frequency and magnitude under various scenarios** include:

- Alumina Limited, which has built its bauxite operations in Brazil to withstand increased frequency and magnitude of extreme weather (Nelson & Schuchard 2011);
- Norsk Hydro, which is raising its facilities in Qatar by two meters to withstand flooding (Nelson & Schuchard 2011); and
- Vale, which monitors weather that could affect railways and ports, and communicates this information across the company. It is also installing a radar-supported weather monitoring system at its ports to detect and forecast storm in time to shut down and secure equipment (Nelson & Schuchard 2011)

The above actions and those in the following sections, will help manage and potentially reduce insurance premiums, workplace health and safety disputes, damage to company and neighbouring property, as well as legal damages claims that could result from poor management of risks. Many of these outcomes will also contribute to maintaining a social license to operate.

Drought

Ensuring access to water (sometimes referred to as 'water security') is a problem that is increasingly recognised by government, non-government, and industry organisations. Unlike the sudden and overwhelming impact of flooding and storm events, extreme dry weather in Australia is a cyclical and, in some areas, a chronic problem. For this reason, many mining operations are able to prepare for and manage constraints on water availability with some degree of predictability (until a flood arrives). However, the prospect of reduced water availability, and/or more extensive periods of dry weather in future, has the potential to significantly impact water-dependent operations.

New operations are facing higher initial establishment costs due to increasing concern and higher standards for management of water. Existing operations wishing to expand at existing sites are being asked to recognise and manage the cumulative impacts of their water use. Case study examples provided here illustrate the benefits of taking a pro-active approach to efficient use of water, particularly in an area where there are other significant land uses, such as agriculture.

As with flooding and storm events, impacts and risks from drought conditions can be direct, indirect, or a combination of the two and there needs to be a change in mindset in planning which allows for both drought *and* flood.

Direct impacts from drought and extended dry periods can occur when there are sudden and significant reductions in the water available for mining and processing operations, such as when water restrictions are applied or increased at comparatively short notice. The types of risks and impacts that might occur under these circumstances relate to:

- Inadequate supply to undertake critical processes;
- Loss of production capacity and failure to meet contractual commitments
- Inability to adapt equipment and infrastructure to a reduced supply, or to lower quality alternative supply.

Indirect impacts can also powerfully affect mining and processing operations. Increased frequency or extended duration of dry periods can create or intensify conflicts with local communities and businesses regarding use of common water sources. Such conflicts, if not appropriately addressed by mining and processing operations, can reduce the social licence to operate at one or more sites in the affected region.

A more complex indirect impact, demonstrated by flooding in Queensland in late 2010, is that while many mining operations in Australia put a great deal of effort and expense into dams and other types of water storage, having a maximum capacity of water stored on site can increase the risks associated with flood. Therefore, it is valuable to investigate alternative measures, such as reducing the need for water in operations, or reusing existing water resources.

Impacts & adaptation options

Case-study mines, demonstrate how mining and mineral processing operations are using different approaches, techniques and measures to identify, plan for and manage risks and impacts from drought conditions.

Following a standard risk-management process to identify new or increased risk, modifying existing processes to address potential for equipment damage or failure, and lost production, the following case-study mines show how mining and mineral processing operations can avoid or limit the impacts by:

- Using long and short-term water balance models to assist in making day-to-day decisions and to simulate supply, demand and storage requirements under various climatic scenarios (Australian Centre for Sustainable Mining Practices 2011; Nelson & Schucard 2011);
- Use of Water Accounting Framework for the Minerals Industry (MCA and SMI, 2012);
- Developing or adopting processing technologies and strategies that reduce water consumption, and increase water conservation (Nelson & Scuchard 2011; AGIC 2011); and
- Monitoring and reviewing the risks, data, and measures, on a regular basis to ensure that these are as accurate as they can be.

Examples of **using long and short-term water balance models to assist in making day-to-day decisions and to simulate supply, demand and storage requirements under various climatic scenarios** include:

- Xstrata Coal NSW developed short and long-term water balance models to assist in decisions about water transfers, discharges and licence allocations (short-term) and plan for changes to supply, demand and storage requirements over the life of the mine (Australian Centre for Sustainable Mining Practices 2011); and

- Newcrest Minerals was a participant in the Minerals Council of Australia (MCA) 2008-2009 pilot Water Accounting Framework – now formally adopted by the MCA – and so far has reported a 77% level of water reuse and recycling in operations (Newcrest Mining Limited 2011). Newcrest Mining has identified a potential savings of 400 ML in evaporation through the transfer of excess water from decanting areas to dams (Newcrest Mining Limited 2009). Other water savings have been identified by Newcrest through replacement of gland seals with pump seals (480 ML/year) as well as piloting higher tailings density to reduce need for increased water usage rates with increased production (Newcrest Mining Limited 2009).

Examples of **developing or adopting processing technologies and strategies that reduce water consumption, and increase water conservation** include:

- Rio Tinto has used its ‘Excellence in Water Management’ diagnostic methodology at more than 25 of its operations. This approach takes the operation from initial risk-based performance assessment relative to key performance areas (KPA), to risk reduction opportunity workshops and finally to project planning and scheduling of prioritised action plans (Australian Centre for Sustainable Mining Practices 2011);
- Kinross has built redundant water storage facilities to contain process solutions and capture rainwater for use (Nelson & Schucard 2011); and

- Exxaro is currently implementing a series of water efficiency projects across its business units, including: the reuse, as process water, of water recovered from slimes disposal facilities; dry beneficiation processes; the capture, reuse and recycling of rainwater, pit water and storm water run-off in operations; and the use of seawater as process water is plant operations (Exarro, 2012).

Examples of **exploring investments in ecosystem services that improve quality and increase availability of local water supplies to meet the needs of the company and community** (Nelson & Schucard 2011) include:

- Vale has commissioned the National Institute for Space Research of Brazil to assess vulnerability under different climate change scenarios in northern and southern Brazil and their effects on factors such as water availability and biodiversity (Nelson & Schucard 2011); and
- The Emalahleni water reclamation plant, built by Anglo American and BHP Billiton in Mpumalanga, South Africa, was originally designed to deal with operational risk and safety issues associated with rising underground mine water. The plant now purifies over 25 ML of potable water daily, providing 18 ML to nearby local municipalities while meeting all the company's operational water needs (AngloAmerican, 2010).

Higher temperatures

High temperatures can affect workers and equipment at any phase of mine development. Exploration teams and those working on the surface in high temperatures can be affected by the heat and by exposure to the sun. Those working in open pits may suffer from the same conditions. Underground workers face different conditions but no less risk. Heat stress affects industrial workers health (through heat-related illnesses), safety (impeding abilities to perform tasks in already dangerous conditions), productivity (due to the slow pace of work necessitated in thermally stressful environments), and morale. High temperatures may also affect energy supply, and reduce the efficiency of machinery. Increasing and extended periods of higher than average temperatures can lead to health impacts for site-based workers, but may also be something that affects off-site workers, as well as local communities.

An indication of how higher temperatures might affect risk at mining and mineral-processing operations can be seen in the links between higher summer temperatures and increased accident and injury among workers in the mining industry (Bedford & Chrenko 1974). Heat stress can cause fatigue, and increase the risk associated with the operation of heavy machinery (WorkSafe Victoria, 2012). Higher temperatures can also place additional strain on transmission and distribution systems through temperature fluctuations and lead to disruptions to supply. In tropical locations, where there are significant populations of mosquitoes, there is also potential for mosquito-borne diseases to affect site personnel and local communities. Bushfires may also be more difficult to manage under drought conditions.

As with other extreme weather events, extended periods of higher temperatures create both direct and indirect risks and impacts as outlined below.

Direct impacts include:

- Threats to the health and safety of work staff and nearby communities (the exposure of workers to extreme heat can result in serious illnesses and injuries, and even death); and
- Reduced productivity due to:
    - Increasing levels of stress, illness and/or injury for site personnel and nearby communities;

    - Increased strain on transmission and distribution facilities and reduced efficiency or lifespan for electrical equipment due to poor power quality; and
    - Increased levels of maintenance, or more frequent servicing, to keep machinery functioning under conditions that are different to the design specification.

Indirect impacts from higher temperatures also need to be considered. For example, responding to higher temperatures, or longer periods of high temperatures, can:

- Increase pressure on energy supplies and create conflict with other users (Loechel et al 2010);
- Increase costs for maintaining a working environment that is well suited to workers and machinery; and
- Increase the opportunities for transmission of some diseases, putting:
    - Workers at risk when they are on site but not actually ‘working,’ and
    - Near-by communities at risk.

Risks from extended periods of higher-than-average temperature are many and varied. Areas that are generally hot and wet will face different risks to those that apply in areas that are hot and dry, while areas that are usually cool and dry will be subject to different risks again. Differences in geography, and seasonal weather conditions, are important to planning for and managing impact. Similarly, being aware of the impact of these changes for local businesses, and communities, is important for understanding risks to those stakeholders and to site personnel.

Success in reducing or eliminating such risks will require awareness of the impacts of longer periods of higher temperatures, and ensuring that existing systems and procedures will be effective under these changed conditions.

Impacts & adaptation options

The prospect of higher temperatures over more extended periods of time, increases the risks of heat-related stress, heat-related illnesses and equipment failures. Examples of how international mining operations are adapting to some of these risks include:

Examples of **modifying existing risk-identification processes to incorporate health risks** include:

- Harmony Gold Mining has introduced a malaria-awareness campaign to promote early diagnosis (Nelson & Schucard 2011);
- Cameco has implemented a pandemic preparedness procedure as part of its emergency planning (Nelson & Schucard 2011); and
- Cameco has also engaged with Saskatchewan Fire Services to conduct an independent audit of its mitigation controls and response measures for forest fires (Nelson & Schucard 2011).

Options for **evaluating and implementing identified opportunities to reduce the risks and impact of heat sources on workers and equipment** include:

- Instituting screening, acclimatisation, and safety procedures for high temperature surface and underground industrial workers; and

- Providing training in identifying health and safety issues for supervisors and workers including symptoms, hazards, and preventative measures associated with:
    - Diseases such as malaria, dengue fever, Ross River Fever, Murray Valley Encephalitis and Kunjin virus;
    - Heat stress; and
    - Food handling related operational health and safety.

3.3 More recent research

Over the duration of the project (late 2011 and early 2013) more material has been developed as a result of activities undertaken through NCCARF, CSIRO, Infrastructure Sustainability Council of Australia (formerly the Australian Green Infrastructure Council), the Australian Government's then Department of Climate Change and Energy Efficiency, and others. This material has been incorporated into the guide where this has been possible and deemed appropriate for the intended audience.

4. DISCUSSION

Navigating the complexities of addressing ‘climate change adaptation’

A key finding of the research regarding the first of the project’s objectives is that there are considerable barriers to assessing the level of readiness for ‘climate change adaptation’ in the minerals industry. The most prominent of these are a lack of consensus about the meaning and legitimacy of the concept of ‘climate change’ within one of the industry’s largest professional organisations.

As a result, the project has taken a more cautious approach to the task of:

1. Articulating the goals of the consultation processes
2. The framing of questions within these consultation processes, and
3. The development of the guide with a focus on adapting to extreme weather.

This lack of consensus, and the prospect of creating significant conflict within the organisation, has made it difficult to justify the presentation of ‘climate change’ and ‘climate change adaptation’ in the manner anticipated under the terms of the project’s original second objective. Whilst specific discussions with targeted groups of stakeholders have been constructive, it has not been possible to comprehensively ‘Engage AusIMM members with the issue’ and whilst adaptation measures were identified, the construction of a program of adaptation ‘pathways’ would be strongly contested by some proportion of the identified end-users.

Consultations with the AusIMM Sustainability Committee and steering committee of the AusIMM Global Greenhouse and Energy panel together with AusIMM policy advisors, have been very useful. This group is aware of the divergent views that are present within the AusIMM and in the wider industry. With guidance from this group, it has been possible to undertake consultation, raise awareness, evaluate some part of the readiness of the AusIMM membership for a range of climate change impacts, and to assess what may prove useful in terms of facilitating adaptation.

Given the ultimate project outcome of producing a useful guide that would engage, and provide value for a wide range of mining and mineral production professionals, the decision was made to focus on aspects of climate change that are both already familiar to this group, and which are already presenting an increasing risk to the viability of operations.

Consultation work within the Steering Committee assisted in the development, promotion and implementation of a members’ survey on experience, knowledge and skills related to extreme weather events. The results of this survey provided information to AusIMM about how it could begin incorporating this kind of information or training into a future schedule of events for AusIMM members. The addition of an interview component usefully captured the sizeable experience of interested members. A point made by all four of the interviewees (with more than 100 years of experience of extreme weather events between them) is that the experience that they have to offer is now difficult to acquire given the comparatively short period of employment that is now available with many companies. Importantly, some interviewees noted that the average period of employment for ‘non-professional’ mining employees is now consistent with that of corporate level professionals (around 5 years) which contrasts the long time scales over which operations exist (and even longer for tailings dams).

Overall, this project has made an important contribution to beginning the task of raising awareness and engagement with the issue of climate change adaptation and the role of minerals industry professionals in response. A difficult subject has been opened up, creating an avenue for engaging the wider membership in a longer-term discussion of impacts and implications – for AusIMM, the industry, but also the research community and universities training the next generation of geologists and mining engineers.

Furthermore, the production of a guide to adaptation delivers on the important task of synthesising both current information on climate change for Australia and case studies of practical adaptation options from disparate sources. This is likely to be of interest, not only to Australian minerals industry professionals, but given the lack of practice-based publications on the topic, also to Australians working internationally and a global audience. It positions both NCCARF and AusIMM at the nexus of research into the changing needs of professionals in the minerals industry.

The following section provides a summary of the gaps that the project team encountered during the course of the research, and outlines potentially useful future research directions.

Adaptation practice and options across areas of drought, flood, bushfire, extreme temperatures

Taken as stand-alone events, flooding and drought risks are reasonably well understood. Though increasing severity of such events can, and has, created significant impacts in recent years, additional complexity arises from movements between extreme wet and extreme dry over a short period of time. A key outcome from the final report on the flooding that affected Queensland at the end of 2010, was the recommendation for water storages to be reduced and proactively managed under potential flood conditions.

Further complexity arising from extreme weather events comes from the specific circumstances of managing mining workforces. Indirect impacts, such as flooding or heat-related impacts that occur in capital cities where mining workforces are living, can also have an impact on operations. This type of indirect impact from extreme weather can also affect the availability of emergency services personnel.

Learning to read the landscape

A useful approach to embedding adaptation into practice was identified following interviews with practitioners as 'learning to read the landscape' (see Appendix 6/7).

This can come from a careful assessment of:

- 'Ephemeral' creek lines (significant indicators of where trouble can be expected in extreme weather events);
- Existing drainage patterns (man-made and natural), and other evidence of impact from extreme weather events – particularly when planning infrastructure design or site development; and
- Drainage dynamics and impacts when post-event water releases happen.

A further point made by those interviewed, was that this type of information should be gathered and analysed early, preferably before the site facilities are constructed. If not, it may be difficult to address risks where changes conflict with existing plan of operation and the environmental conditions that are attached to the plan of operation. Whilst these points were based on practitioner experience – a standardised approach to understanding who holds required landscape knowledge and where the key points are to use it in mine planning would be helpful.

Awareness of changes to the weather across short (12 hour forecasts), medium (5 day and seasonal forecasts) and longer-term (annual trends, broader cycles such as El Niño and La Niña) provide the best forewarning of significant events, and provide the best information about the precise nature of an extreme wet weather event. Documentation of impacts from historical events can also be very useful.

Additional data gathering resources suggested by those interviewed included local weather stations, and records from any nearby airfields. If there are no local weather stations in the area, then investing in an ‘automatic’ weather station or two (about $100,000 each) is a worthwhile option given the potential impacts.

5. GAPS AND FUTURE RESEARCH

There are a number of gaps that have emerged as a result of this project. These relate to the:

- Absence of consensus about the foundation and need for 'climate change adaptation;
- Transmission of information between experienced professionals and less experienced professionals; and
- Public availability of information on risk assessment, preparedness and management for climate change at sites.

5.1 Exploring absence of consensus

A key determinant of the project's success to date has been the ability to negotiate the sensitivities associated with the term 'climate change' amongst this end user group. Comments from the initial steering committee workshop indicated that while 'adaptation' to 'extreme weather events' might be acceptable as a framing mechanism for the research, 'climate change' would be unnecessarily divisive. Further progress in understanding the adaptive capacity of professionals in the mining and mineral processing industry would be assisted by having a more precise understanding of where these divisions are located. An exploration of generational, discipline-based and personal alignments on the concept of climate change (anthropogenic or otherwise) would be very useful in finding ways to resolve existing tensions.

Finally, there may be great value in the adoption of a 'whole-of-government' approach to recognising the potential impact and implications of extreme weather events. A clear signal regarding the importance of climate change adaptation measures will provide greater clarity for the industry about the 'materiality' of such measures to a range of key stakeholders, including the community and financiers where a lack of adaptation planning could affect social licence to operate.

5.2 Learning from experience

Consultation activities, particularly workshops and interviews, indicate that there is a great deal of mining expertise within Australia that is becoming less accessible due to changes to the ways that workforces are deployed at sites, and through the retirement of professionals with decades of experience. Interviews indicated that today's professionals are less likely to spend long periods at a site, and their association with those sites is increasingly remote and/ or disrupted by workforce management styles associated with Fly-in-Fly-out and Drive-in-Drive-out operations (e.g. two weeks on, one week off).

There is now a critical window of opportunity to engage with retired professionals to harness this experience and disseminate it to the larger membership.

Another point for further investigation that was raised from the interviews is that decisions made prior to any detailed construction planning have an impact on subsequent capacity for adaptation. Incorporating adaptive capacity into a whole of life cycle management approach is likely to be very helpful for any new operation.

5.3 Broader policy landscape

As noted in previous sections, the legislative and regulatory environment of mining and mineral processing operations is changing. The current research looked specifically for climate change related legislation, and found it to be extremely dynamic. For example, the legislation to put in place a carbon price had not been passed at the time of the literature review. Ongoing changes to broader adaptation policy responses such as changes to planning regimes (particularly in coastal regions) and climate change considerations in Environment Impact Assessment processes, both of which are relevant to the mining industry, would be useful areas for further research. In cases where mining or mineral processing operations are situated in coastal communities, a comprehensive resource on the relevant policies and strategies as well as legislation which is applicable is provided by Gurran et al. (2011) and is reproduced in Table 3.

Table 3: Summary of legislation pertaining to climate change adaptation planning in coastal Australia

State / Territory	Key Policies / Strategies	Key legislation / regulations
NSW	NSW Sea Level Rise Policy Statement (2010) NSW Coastal Planning Guideline (2010) NSW Coastal Policy (1997) NSW Coastal Design Guidelines (2003) Coastal Risk Management Guide (2010) Flood Risk Management Guide (2010)	*Coastal Protection Act 1979 and Coastal Protection Regulation 2011* SEPP 71 Coastal Protection (under *Environmental Planning and Assessment Act 1979*) *Environmental Planning and Assessment Regulation 2000* (amended in early 2011 to require that coastal hazards affected by sea level rise be noted on 'section 149' planning certificates)
Northern Territory	Climate Change Policy (2009) Coastal Management Policy (and) Implementation Strategy 2001, under review	Northern Territory Planning Scheme (addresses flooding and storm surge, as well as 'Primary' and 'Secondary' storm surge areas)
Queensland	*Queensland Coastal Plan 2011* (adopted, not yet commenced) *Climate Smart Adaptation: 2007-2012* *Action Plan* *State Coastal Management Plan* (2002) (nb: to be superseded by the *Queensland Coastal Plan 2011* when it comes into effect)	*Sustainable Planning Act 2009* (refers to climate change and sea level rise) *State Planning Policy for Coastal Protection* (provisions for addressing potential climate change impacts; N.B.: *part of the Queensland Coastal Plan*) *Coastal Protection and Management Act 1955*

State / Territory	Key Policies / Strategies	Key legislation / regulations
South Australia	South Australian Planning Strategy (includes climate change adaptation) *Coastline: Coastal erosion, flooding and sea level rise standards and protection policy (1992)*; source of sea level rise provisions included in all SA Local Development Plans Living Coast Strategy (2004) (recognises the risk of climate change, sea level rise, and coastal hazards, and the need to incorporate in local planning. Draft Climate Change Adaptation Framework (2010) (proposes regional vulnerability assessments, agreements and adaptation plans)	*Coast Protection Act 1972* (established Coastal Protection Board) which develops coastal planning policy and is a referral body for coastal development
Tasmania	Framework for Action on Climate Change (2008) (under review) Climate Change Impact Statements Draft State Coastal Policy 2008	*State Coastal Policy Validation Act 2003*
Victoria	Victorian Coastal Strategy 2008 Coastal Action Plans and Coastal management Plans (West Coast, Central Coast, and Gippsland Coast) – mechanism for implementing the coastal strategy	*Coastal Management Act 1995* (established the Victorian Coastal Council and 3 regional Coastal Boards, influential in promoting climate change adaptation in coastal Victoria). *Climate Change Act 2010* (requirement to consider climate change in developing coastal strategies / actions plans under *State Planning Policy Framework* addresses coastal hazards and coastal impacts of climate change
Western Australia	Draft Coastal Zone Management Policy for Western Australia (June 2011)	*Statement of Planning Policy 2.6 State Coastal Planning Policy 2003*

Source: Gurran et al 2011.

5.4 Need for collaborative approach

As noted in previous sections, the advantage or risk that climate change presents to mining and mineral-processing operations makes access to relevant information difficult under existing circumstances. A comment received during feedback processes indicated that there did not appear to be enough 'positive' case study material included in the guide. Most of the more positive case-study materials have been drawn from existing research that has focussed on promoting the efforts of mining and mineral processing operations in reducing energy and water costs or impacts and available through the efforts of industry (see Water Services Association of Australia case studies, Young, 2009) or government supported initiatives (see Department of Resources Energy and Tourism handbooks and Energy Efficiency case studies). While these examples were suitable to extreme weather events such as droughts, they are less suitable to flooding and storm-type events, and examples of the impact and implications of extreme weather events such as flooding and storms have been harder to find.

Consultation with AusIMM members has indicated that some companies are incorporating climate change adaptation into their strategic planning and operational procedure manuals. Future research in this area would benefit greatly by access to these documents, however it is difficult to gain access to information that has potential for commercial advantage or risk. Given the risk that significant failures pose to stakeholder confidence, reluctance to publicise small or large failures of risk assessment and management is understandable. This difficulty has been overcome in other areas through industry and government collaboration in establishing a benchmark for the industry. An industry-wide approach to improving existing knowledge and capacity can be seen in a collaborative approach to addressing abandoned mines in Canada (NOAMI 2009).

5.5 Impact of remote operation on adaptive capacity and emergency management

Survey responses indicated that historical and contemporary knowledge of local conditions was important to effective risk assessment and risk management. Given the current interest in the use of remote operations technology in mining, it would be useful to investigate the impact that this style of site management and operations will have on adaptive capacity to flooding and storm events.

5.6 The role of government, research and professional organisations

In addition to previous points raised, it may also be useful for there to be further consideration given to the role government, researchers and AusIMM could play in creating engagement between:

- Those managing a particular site across the entire life cycle to ensure that the adaptive capacity of one phase is supportive of further adaptive capacity development during later stages;
- Generations of professionals, within the mining and mineral processing industry, to ensure that this knowledge is captured and incorporated into planning and operations and that skills and training needed for new professionals are consistent with adaptive planning skills for climate change adaptation; and
- Companies to accelerate the process of increasing knowledge and capacity for adapting to extreme weather events which bridges the gap in institutional memory between short on-site times for many professionals (months to years) compared with the longer time frames of site operation (years to decades or more).

6. CONCLUSION

This research has occurred at a time of great uncertainty and change to the operational environment of mining and mineral professionals. Impacts from extreme weather events, changes to global trading conditions, and national frameworks for taxation and energy legislation have attracted some attention at the level of the sector, but how these are being experienced and responded to, particularly by professionals in the sector, is not well understood.

The objectives of the project: assessing levels of readiness for climate change adaptation risks in the minerals industry; engaging the 11,000 industry professionals that make up the AusIMM with the issue; and developing adaptation measures and pathways for inclusion in a guide, have been achieved with some difficulty.

Climate change readiness of professionals in the industry is difficult to identify directly as, until very recently, there has been no clear guidance regarding its materiality for regulators and other key stakeholders. Conflicts about the likely causes, impacts and importance of climate change and climate change adaptation are perceptible in the different approaches of state and federal government departments and agencies, and can also be seen in the contentiousness of public discourse or 'debate' on these subjects. In the absence of consensus, there has been a high level of caution in raising these matters within AusIMM. In this situation, the approach to identifying readiness and capacity to adapt has been to focus on extreme weather events as these are already having measurable impacts and the need to develop responses to such events has very clear materiality for most mining and mineral processing professionals.

The involvement AusIMM's sustainability committee has been invaluable, both for the insights that the collaboration has generated with respect to the variety of responses to the issues of climate change and climate change adaptation, and for ensuring that the project was able to involve well-placed end users. This will enable the outcomes of the project to be widely distributed within the industry.

This project has confirmed the substantial, if largely unrecognised, business case for greater engagement with climate change adaptation by professionals within the mining and mineral processing sector. Recognition of this, amongst the sector can be seen in public recognition of its role in by RioTinto (2012):

> *"Climate change will create risks and opportunities for Rio Tinto's businesses that will affect shareholder value. It will lead to significant changes in the physical environments in which our businesses operate. Over the longer term, climate change threatens the stability of natural, social, economic and political systems, which risks significantly damaging the prospects for our businesses."*

This statement also included commentary regarding the anthropogenic nature of climate change and as such represents a significant shift in the public stance of a key player within Australia's mineral industry.

In concluding the project, there are several important aspects of the research that are worth highlighting for their contribution to ongoing engagement with this sector and which may be useful in supporting climate change adaptation amongst professionals in other sectors.

Those aspects that have been assessed through the lens of 'extreme weather events' have revealed a high degree of variability in the readiness of professionals, and the need for improved knowledge sharing between professionals. As illustrated by case-study mines and processing operations, capacity for addressing water scarcity has been fostered by long-term drought conditions in many areas. However, as demonstrated in other case studies, there is less capacity for managing flood conditions, and quick changes between drought and flood conditions. Higher temperature conditions over longer periods are also likely to test existing risk assumptions, and create challenges for a range of operational and support systems.

Changes to historical climatic conditions, combined with the changing costs of production, are likely to increase the efforts required to protect physical assets, worker and community health and safety, and improve the environmental performance of operations before, during, and after extreme weather events. Some guidance and resources exist as a result of increased interest in water and energy efficiency in recent years. Similarly, shifts in the shape and character of global trade have fostered flexible, adaptive planning approaches that can also be drawn upon as a resource for climate change adaptation.

Mining and mineral professionals have key roles to play in meeting the challenges of changing climatic conditions, changing costs, and changing expectations of stakeholders. Increasing frequency or severity of extreme weather events has already required changes to existing infrastructure (i.e. tailings containment, site drainage networks), and will require more than incremental adjustments to assumptions about risks and risk management.

By ensuring that operational responses to these events are well grounded in leading practice and current information this project has sought to make a significant contribution to understanding these issues. As greater consensus about the status and importance of climate change and climate change adaptation emerges, there will be greater opportunity to delve more deeply into more subtle aspects of climate change readiness amongst mining and mineral processing professionals.

APPENDICES

Appendix 1: Documentation of change in project methodology

Proposed Activity (original descriptions and numbering)	**Proposed method and participation** (original descriptions)	**Proposed outcome** (original descriptions)	Implemented Project Activity	Implemented project outcome
1. Establish steering committee & communication plan	Draws on the expertise of the AusIMM Global Greenhouse and Energy Panel (10 persons) to guide research over the life of the project.	Ensure that the direction of research and plan for communication is well grounded in the experience and concerns of end-users.	In addition to input from AusIMM Global Greenhouse and Energy panel, AusIMM Sustainability Committee was involved.	Steering committee members participated in a workshop aimed at understanding how the information from the literature review could be usefully communicated to members of the AusIMM and monthly teleconferences. This discussion was a significant informant of the change in approach to the guide.
2. Literature review on climate change risks and compilation of case studies on business planning for adaptation.	Collect and synthesise information about approaches, processes, and institutions that have assisted with industry adaptation. This will include legislative changes such as carbon pricing, environmental, social and economic impacts from the interaction of mining and mineral processing with flooding and extreme weather events.	Provide an overview of the existing research and business readiness in the area of adaptation to a range of challenges presented by, or related to, climate change. Provide practical examples of adaptation that can be used to focus discussions amongst stakeholders. Case studies deemed most useful by stakeholders will be incorporated into the draft guidelines.	As proposed.	Literature review addressed existing guidance for mining and mineral professionals, information on expected changes to climatic conditions, stakeholder responses to the risks and impacts of climate change, identification of case study material from a range of sources.

Proposed Activity (original descriptions and numbering)	**Proposed method and participation** (original descriptions)	**Proposed outcome** (original descriptions)	Implemented Project Activity	Implemented project outcome
3. Workshop consultation	Engage expertise from steering committee/ AusIMM Global Greenhouse and Energy Panel (10 persons) to provide feedback on preliminary guideline development, review case study material, and provide input on further consultation activities.	To test and further inform preliminary best practice guideline development.	As proposed.	Identified useful case studies and questions to pose in the online survey as well as highlighting the sensitivities around the framing of the project as "climate change" research, following a controversial earlier piece of incomplete research which was to be commissioned by the Global Greenhouse and Energy panel on a review of climate science and risk assessment where there were diverging views amongst AusIMM members.
4. Development of draft best practice adaptation guidelines	Synthesise desktop research and steering committee feedback for circulation as a consultation draft of best practice guidelines.	This process will allow for communicating and testing the analysis of stakeholder inputs around risk, challenges, and the appropriateness of response options.	More time was put into the development of the guide and incorporation of feedback than originally planned, some of which took the place of state based workshops	A draft of the leading-practice guidelines was developed using case study materials identified in the literature review. Early drafts were circulated to reviewers for feedback. Comments from these stakeholders were then incorporated into a consultation draft that was provided to a range of reviewers including two AusIMM committees for feedback. This led to useful material being identified, e.g. bushfires.

Proposed Activity (original descriptions and numbering)	**Proposed method and participation** (original descriptions)	**Proposed outcome** (original descriptions)	Implemented Project Activity	Implemented project outcome
5. Development and distribution of online survey	Feedback on the draft guidelines and adaptation readiness will be sought from AusIMM members and industry via online survey promoted through the AusIMM Bulletin; Week in Review email and at Congress	This will provide a snapshot of the level of readiness by industry. It will also provide feedback on the draft guidelines.	The survey was undertaken as INPUT to the guide (sent to 11,000 members in email newsletter), rather than to get feedback on the guide.	Stakeholder survey data on experiences with the experience and practices of professionals, plus the additional in depth interviews provided very valuable information regarding attitudes of AusIMM members, towards climate change and climate change adaptation, as well as expectations of impact from climate change adaptation measures on the part of external stakeholders. Respondents were asked to provide contact details if they wished to be contacted in order to provide further information. Four of six respondents agreed to be interviewed and this information has been incorporated into the guide as well as communicated through an article in the AusIMM journal published in Feb 2013.

Proposed Activity (original descriptions and numbering)	**Proposed method and participation** (original descriptions)	**Proposed outcome** (original descriptions)	Implemented Project Activity	Implemented project outcome
7. Presentation of draft guidelines to stakeholders	Draft guidelines presented at AusIMM Congress in April 2012 (up to 400 persons) to engage with a broad range of industry stakeholders, many of which are not currently members of AusIMM.	To communicate and engage with a range of stakeholders within and beyond AusIMM	Approach is different to proposal.	A project update on the proposed leading-practice guide, was presented at the AusIMM Congress, rather than a detailed presentation of the guidelines. The research team were unexpectedly unable to attend the NZ-based congress in person and there was a change in AusIMM project manager at the time and a separate space in the program for feedback on the NCCARF project was not secured.
8. State-based stakeholder workshops	Engage with approximately 40 persons across AusIMM state branches. Workshop participants will assess and prioritise a range of options for addressing the challenges presented by climate change.	Further assess the suitability and relevance of the draft guidelines on a wider range of industry stakeholders at different levels.	Approach is different to proposal	The approach taken to getting more considered stakeholder engagement to the draft guide has been to add interviews to the survey phase and to get feedback from the AusIMM Health and Safety Committee, members of the CSIRO Climate Change Flagship research team presently exploring the impact of Climate Change on the mining industry, and AusIMM Sustainability Committee members in addition to steering group members. Interviewees were also been invited to provide feedback.

Proposed Activity (original descriptions and numbering)	**Proposed method and participation** (original descriptions)	**Proposed outcome** (original descriptions)	Implemented Project Activity	Implemented project outcome
9. Finalise and launch best practice guidelines	Incorporate analysis and feedback from industry stakeholders into a clearly presented document that outlines a range of measures and pathways as potential responses to risks identified by desktop research and stakeholder consultation.	Create and launch (print and online) a new resource for developing the adaptive capacity of the Australian mining industry with identification of potential follow-on companies who could pilot use of guidelines.	As proposed	Content for this document has been provided to NCCARF and to AusIMM for final review. Research material from the (see section x for more details)

Appendix 2: Summary of Literature Review

Existing policy, legislation, regulation and programs related to Climate Change Adaptation

New legislation to address climate change reflects the early state of engagement with the potential impacts and implications for a wide range of stakeholders. While the *Clean Energy Act (2011)* introduced a price for carbon for Australia's top 500 emitters from mid-2012, this does not affect all mining and mineral processing operations. However, other legislation introduced at the same time as the Clean Energy Act, and further regulatory and legislative changes being investigated through a Productivity Commission Inquiry may have a broader application to the mining and mineral processing industry. These additional regulatory and legislative instruments create obligations that will require existing skills to be adapted to new circumstances and for additional knowledge and skills to be developed.

Potential impacts and implications arising from changes to historical climatic conditions and responses to climate change by key stakeholders

Risks and costs associated with increasing climatic variability, value protection and creation, and stakeholder expectations are three elements that have been identified as a possible basis for a 'business case' that is relevant to both the mining and mineral processing industry and to professionals within the industry. Three elements have been identified as useful to building a business case for engaging with climate change and climate changed adaptation, namely the need to respond to:

- The impact of recent extreme weather events and to evaluate the risk posed by observed trends towards increased severity of such events
- Obligations to protect 'value' (brand and investments) and opportunities to create value (innovation)
- Stakeholder concerns and responses to observed climate variability and potential for increasing change from historical climatic conditions.

Changes to historical climatic conditions: Many parts of Australia are likely to be hotter and drier (CSIRO 2007; BOM 2012). Some regions will experience more severe extreme weather events and some may become more frequent. Given the variation in the modelled estimates and observed data trends it will be useful to test the minerals industry professionals' awareness and attitude to different foundations through consultation and survey for future development of the leading-practice guide.

Responses and Stakeholder Expectations

Many key stakeholders of the mining and mineral processing industry, including governments, insurers, institutional investors, and members of the public are responding to climate change and climate change adaptation. This response by stakeholders creates both mandatory and voluntary drivers for the mining and mineral processing industry to engage with climate change adaptation.

Case studies that can be used as examples of potential impacts or leading practice

Some companies are evaluating or implementing actions that both improve performance in areas such as biodiversity protection or water use and increase the ability of natural systems to absorb greenhouse gases (Wentworth Group, 2009).

Methods for operating in an environment of high uncertainty

Methods for operating in an environment of high uncertainty including risk assessment, planning, implementation, as well as processed for monitoring and evaluating progress represent a large body of information across several discipline areas. Considerable resources for undertaking risk and opportunity assessment exist for different sectors of business. Several have been developed with natural resource development projects in mind, however there are also resources prepared for other users that can be usefully included in a leading-practice guide.

Important terms and definitions

There are a number of different definitions for climate change adaptation used by different organisations. A broad definition was adopted as a basis for opening a discussion of climate change adaptation initiatives and measures that could be adopted by the mining and mineral processing industry. With this aim in mind, “climate change adaptation” has been defined as: any adjustment made by individuals, governments or organisations to expected or actual changes in climatic conditions. A range of other terms has also been provided as part of the literature review, in a list of ‘useful terms’.

Potential options for adaptation

Examples of climate adaptation can be seen in actions being taken to assess the risks of higher temperatures, lower rainfall, increasing frequency and or severity of ‘one-in-one-hundred year’ weather events (Nelson and Schuchard, 2011). Climate change adaptation can also be seen in planning for new infrastructure that seeks to reduce or eliminate the impact of flooding events, and in retrofitting initiatives that relocate or reinforce existing infrastructure against such events (AGIC, 2011). Climate change adaptation can also be seen in actions that reduce the energy intensity of operations or change the energy mix to lower the emissions of carbon dioxide from routine operations (Hodgkinson et al., 2010; Nelson and Schuchard, 2011).

Existing skills, knowledge and expertise of mining and mineral professionals

The literature review revealed that existing leading- practice manuals for the mining sector made little or no reference to ‘climate change’ or ‘climate change adaptation’. Identifying useful case studies was seen by the steering committee as a key element to engaging the intended audience. However, due to the commercial-in-confidence nature of mining corporations’ risk management and planning manuals, it is difficult to find information about relevant events or practices. Where these have been found, it has been due to the public nature of disastrous failure of mining operation systems, which have resulted in coverage by media, proceedings by government or courts. For this reason, the majority of the most relevant material for Australia is quite negative.

Analysis of implications for knowledge and skills of mining and mineral processing professionals indicated that there may be significant benefit in approaching the guide as an extension of existing competencies in risk assessment, risk management and health and safety practices.

Appendix 3: Summary of Steering Committee Workshop outcomes

The Steering Committee were presented with key findings from the literature review and asked to provide feedback about the information that they found most useful. This elicited the following suggestions:

Approach to engaging audience

One informant suggested that a clear outline of the state of 'preparedness' and engagement with climate change be provided. Another response indicated the need to acknowledge the diversity of mining and mineral industry professionals:

"Professionals will want to know what affects them - there will be different consideration for explorers versus miners so this could be considered."

The discussion also indicated that the AusIMM audience may not be as widely distributed across the 'life of mine' as originally assumed – therefore the life of mine phase approach to structuring the document (as taken in the Leading Practice Sustainable Development handbooks) has been questioned. There was also a great deal of support for case studies – particularly those that have had a high profile, such as Ensham. One informant suggested that the case studies become a 'structuring element' through which different implications and options can be explored.

Content for survey (and broader guide)

Based on consultation with the Steering Committee guidance on the structure of the AusIMM member survey (and indeed the guide itself), concern was raised about how to approach awareness raising and guidance regarding adaptation without provoking conflict relating to the causes of 'climate' change and even the relationship of extreme weather to natural or anthropogenic climate variation. Beyond this, the steering committee indicated that:

- Case studies were likely to be a key element to engaging the intended audience.
- Drought conditions would be a useful element of 'extreme' weather conditions that could be addressed in the leading-practice guide.

  "Before the Business Case, there is a needed to review and summarise the CC adaptation status in the minerals industry. There is an implication that because there is little research in this area in the minerals industry there is little evidence of adaptation, whereas there may be quite a bit (I don't' know but the case studies raised during the workshop indicated the need to closely engage with industry to determine this rather than say 'this is what you should do....first find out what leading-practice operations have done or are doing...) so there needs to be the knowledge base/starting point which says this is what we know about where we are now and then this is where we are heading to...and this project will help us get there by...."

In response to the question of whether there were "any parts of the research [literature review] that you found particularly useful?"

"review of IPCC and CSIRO impact models"

"Impacts and implications Adaptation Developing strategies for adaptation (other approaches from different regions/industries)"

"The proposed adaptation case studies about best practice in response to different weather conditions that will affect mining operations - rising sea levels may be contentious but would [affect] some aspects of operations - so why not."

In answer to the question: “Has the research overview provided to you at the workshop missed anything that you consider to be of critical importance to professionals in your area of work?”, the following responses were received:

“AusIMM Policy position on Climate Change Suggest any further work goes to the “how to’ practical integration within the business i.e. tools for gap analysis (how prepared is my business), how to integrate into risk assessments (template?), incorporating into disaster management planning, what to consider in forward looking contracts for external suppliers.”

Framing

Language issues have been a key part of negotiating the conflicts raised here.

Issues raised with the committee were the need to engage sensitively but assertively with the intended audience. Responses from steering committee indicate that there are likely to be responses to ‘climate change’ that will not be present for ‘adaptation’ to extreme weather events.

Appendix 4: Documentation of AusIMM Members survey instrument

Exit this survey

AusIMM THE MINERALS INSTITUTE | Institute for Sustainable Futures | UNIVERSITY OF TECHNOLOGY SYDNEY | NCCARF National Climate Change Adaptation Research Facility

NCCARF Mining Leading Practice - Adaptation to extreme weather

Thank you for taking the time to participate in this research.

This survey is aimed at understanding AusIMM members' experience of extreme weather events, and the skills or knowledge required to manage the direct and indirect impacts of such events.

There are 9 questions in this questionnaire.The first 6 questions will be used to help the Institute for Sustainable Futures and AusIMM develop leading practice guidelines for planning and preparing for extreme weather such as severe storms and flooding,drought and extreme temperatures.

The second 3 questions will be used to assist AusIMM in developing training and other resources for AusIMM members.

All responses are anonymous, but there will be an opportunity to provide your contact details if you would like to make further contributions or provide additional feedback. All contact information provided will be used only for this purpose.

1. What is your present role in the mining and mineral industry (if you are retired, please tell us about the role you were most involved with)

2. Which area of AusIMM membership are you affiliated with?

- ☐ Mining
- ☐ Metallurgy
- ☐ Geoscience
- ☐ Environment
- ☐ Management
- ☐ Other (please specify)

20%

Next

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NCCARF Mining Leading Practice - Adaptation to extreme weather

These questions help us understand what skills and knowledge are useful in successfully analysing, planning for, or managing extreme weather events at mining and mineral processing operations.

4. What were the skills or knowledge that you used when you were analysing, planning for, or managing the impacts of extreme weather events?

5. Were there other skills or knowledge that you believe would have been useful to you in that situation?

- Yes
- No

Please tell us about the skills or knowledge that you would have found useful (below)

6. Are there examples of best practice that you believe would be useful to other professionals in analysing, planning or managing the risks and impacts of extreme weather events? Please tell us about them in the space provided here:

60%

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NCCARF Mining Leading Practice - Adaptation to extreme weather

7. Do you expect your role to change, in any way, with the introduction of the Clean Energy Future legislation?

- ○ Yes
- ○ No

Please tell us about how or why the legislations affects you in your role

8. If you needed to know more about dealing with NEW REGULATIONS and LEGISLATION, what would be the most useful way of making it available to you?

	Most useful	Useful	Not useful
Seminar or workshop at my local branch	○	○	○
Fact Sheets (online or printed)	○	○	○
Leading Practice Guidelines (online or printed)	○	○	○
Articles in the AusIMM Sustainability Newsletter	○	○	○
Articles in the AusIMM Bulletin	○	○	○

Other (please specify)

9. If you needed to know more about dealing with the PHYSICAL or LOGISTICAL ISSUES of extreme weather events, what would be the most useful way of making it available to you?

	Most useful	Useful	Not useful
Articles in the AusIMM Bulletin	○	○	○
Seminar or workshop at my local branch	○	○	○
Leading Practice Guidelines (online or printed)	○	○	○
Articles in the AusIMM Sustainability Newsletter	○	○	○
Fact Sheets (online or printed)	○	○	○

Other (please specify)

80%

Back Next

Exit this survey

NCCARF Mining Leading Practice - Adaptation to extreme weather

We appreciate your input, and any additional information or feedback you may wish to provide.

If you would like to make additional contributions to the Leading Practice Guidelines, please provided us with your details below.

10. If you would like to make further contributions to the Leading Practice Guidelines, please provide your name and phone or email contact details.

Name:

Company:

Email Address:

Phone Number:

If you have questions about the role of AusIMM in this project, please contact Sarah Gafforini on +61 3 9658 6100.

If you have any concerns about how the results of the survey will be presented or managed, please contact Leah Mason at the Institute for Sustainable Futures (University of Technology, Sydney) on +61 2 9514 4909.

This work is being carried out with financial support from the Australian Government (Department of Climate Change and Energy Efficiency) and the National Climate Change Adaptation Research Facility. The views expressed herein are not necessarily the views of the Commonwealth, and the Commonwealth does not accept responsibility for any information or advice contained herein.

100%

Back Done

Appendix 5: Summary of AusIMM Members survey result data

Research undertaken by AusIMM in collaboration with the CSIRO[1] indicates that 'environment' is deemed to be a significant concern for mining and mineral processing professionals. However, the experience of the project team indicates that, at present, "climate change" is not a topic that can be raised without creating conditions of conflict that are unsuitable for undertaking further research. Early consultation within the project Steering Committee assisted in the development, promotion and implementation of a members survey on experience, knowledge and skills related to "extreme weather events".

Of the 47 participants who started the survey during the survey period, 95% provided details of their role in the mining and mineral processing industry, and their affiliation with AusIMM professional group. Slightly less than 66% provided answers to all questions, however those without experience of analysing, planning or managing extreme weather events were not required to answer further questions about this. A summary of the survey results is provided here, and full results are provided in the appendix of this document.

Survey respondent characteristics

45 participants in the survey provided information about their role as a mining and mineral professional. Of these 71%(32/45) were directly employed by a mining or mineral processing company, while 24%(11/45) indicated that they were 'consultants'. Approximately half (23/45) of these respondents appeared to occupy a senior role (engineers and senior technical staff), with several respondents nominating themselves as a CEO, directing manager or manager of a mining or consulting company. At least one respondent appeared to be related to government.

All 47 respondents (100%) to the survey provided information about their AusIMM affiliation.

The graph below shows the professional affiliation of this group. More than half nominated "Mining", while slightly more than a quarter nominated "Geoscience".

[1] Moffat, K., Mason, C., & Littleboy, A. (2009). Preparing for uncertain mineral futures: A survey of AusIMM members on the future issues and drivers for the Australian minerals industry. Paper presented at the Sustainable Development Indicators in the Minerals Industry (SDIMI) Conference, , Gold Coast, Queensland, Australia

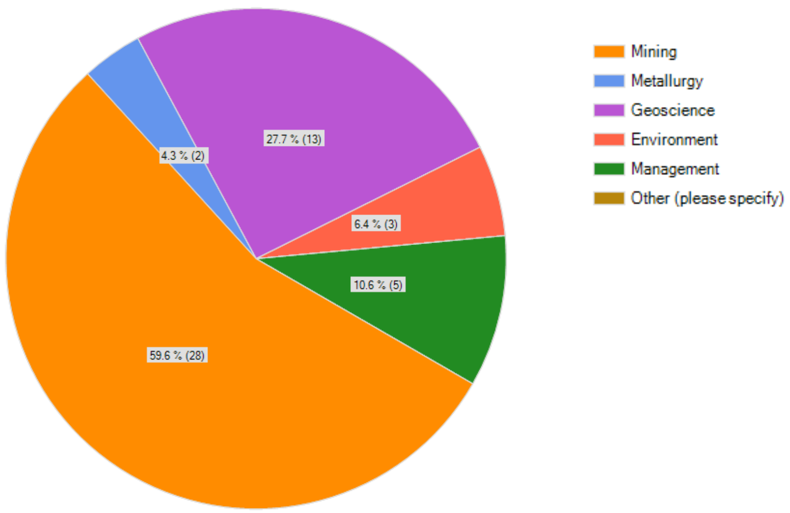

Figure 3 Affiliation of survey respondents to AusIMM professional group categories Respondent experience of extreme weather events

Forty-five respondents (96% of all respondents) provided information about their professional experience of preparing for, or managing extreme weather events. Six respondents declared that they had no professional experience of extreme weather, and two indicated that they had professional experience of extreme weather at a mine site that they were not employed, or in another industry. The figure below shows the spread of experience across these respondents:

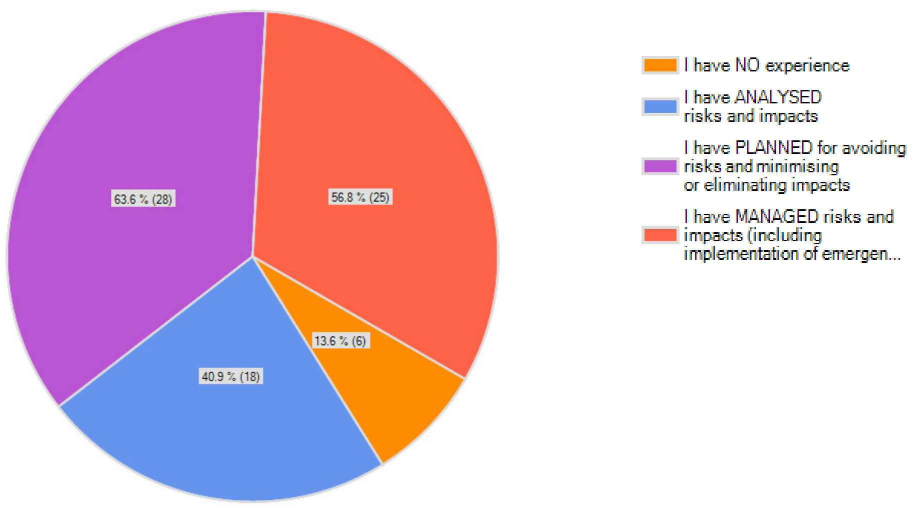

Figure 4 Experience of analysing, planning and managing risks and impacts of extreme weather events.

Further analysis of these responses showed that less than half of the 45 respondents had analysed risks (18/45), however more than half indicated that they had experience of planning for extreme weather (28/45), and over half indicated that they had professional experience of 'managing' responses to extreme weather (25/45). Within the group that had experience of managing, slightly less than half (12/25), also had professional experience of analysis and planning for such events.

Respondent views of useful skills and knowledge

30 of the respondents who indicated that they had some experience of extreme weather events at mine sites provided further information about the skills and knowledge they considered to be useful to professionals in that situation. These responses have been categorised into 21 broad categories. Analysis of the responses has provided some sense of where efforts to increase awareness and capacity might be usefully centred. As noted earlier, 12 of the respondents to the survey indicated that they had professional experience of analysing, planning and managing extreme weather events, and within this group 11 nominated skills or knowledge that were useful to them in those situations. Table 5.1 (below) shows the relationship of the responses of these participants (AMP) to the broader group of 30:

Table 4 Comparison of skills and knowledge nominated by survey respondents

Category	Respondents	AMP	AMP / total	
Experience with Extreme Weather Events	9 (30%)	3 (27%)	33%	*
Interest in weather forecasting/meteorology	11 (36%)	4 (36%)	36%	*
Communication	5 (17%)	1 (9%)	20%	
Local knowledge	5 (17%)	2 (18%)	40%	
Hydrology	8 (27%)	3 (27%)	38%	
Historical data	7(23%)	3 (27%)	43%	
Emergency psychology	2 (7%)	1 (9%)	50%	
Crisis management	3 (10%)	1 (9%)	33%	
Risk assessment	12 (40%)	6 (54%)	50%	*
Risk management	9 (30%)	6 (54%)	66%	*
Technology	2 (6%)	2 (18%)	100%	
Preparation	6 (20%)	5 (45%)	(83%)	**
Operations knowledge	2 (7%)	1 (9%)	50%	
Emergency management	4 (13%)	3 (27%)	75%	
Regulatory knowledge	2 (7%)	1 (9%)	50%	
Modeling	2 (7%)	1 (9%)	50%	
Scheduling	3 (10%)	3 (27%)	100%	
Understanding of financial impacts	4 (13%)	1 (9%)	25%	
Engineering experience	5 (17%)	2 (18%)	40%	
Geotechnical knowledge	4(13%)	1(9%)	25%	
Prescience	0	0	0%	

As can be seen from this table, there are a broad range of skills and knowledge nominated by respondents. Areas highlighted in red are areas that have nine or more responses. Areas highlighted in pink indicate that over half of the AMP group respondents have contributed to this total.

Comparing these broadly defined skills and knowledge categories into which all of the responses have been distributed to those of the 11 respondents with the widest breadth of experience (analysis, planning and management), it can be seen that there is most agreement around the usefulness of risk assessment, risk management.

Responses that received support from nine or more of the total group of respondents (30% of those answering this question), have been outlined in table 5.2 (below):

Table 5 Five most nominated areas of useful skills and knowledge

	Skills and knowledge	respondents
1	‘Risk assessment’	12
2	Weather or meteorological information	11
3	Experience of extreme weather events or access to people with this experience	9
4	Risk management	9

A second question aimed to elicit additional skills and knowledge that have been or may be useful in analysing the risk, planning or managing extreme weather events. Responses to this question have been added to the totals in the previous table.

Table 5.3: Additional skills and knowledge nominated by survey respondents with experience of extreme weather events.

Category	AMP	Broader	Total (%)	
Experience with Extreme Weather Events	0	1	10 (33%)	*
Interest in weather forecasting/meteorology	0	3	14 (47%)	
Communication	1	2	8 (27%)	
Local knowledge	1	3	9 (30%)	*
Hydrology	1	3	12 (40%)	*
Historical data	0	1	8 (27%)	
Emergency psychology	0	0	2 (7%)	
Crisis management	0	1	4 (13%)	
Risk assessment	1	2	15 (50%)	*
Risk management	1	1	11(36%)	*
Technology	0	0	2 (7%)	
Preparation	1	2	9 (30%)	*
Operations knowledge	1	1	5 (17%)	
Emergency management	0	0	4 (13%)	
Regulatory knowledge	1	2	5 (17%)	
Modeling	0	2	3 (10%)	
Scheduling	0	1	4 (13%)	
Understanding of financial impacts	1	0	5 (17%)	
Engineering experience	1	2	8 (27%)	
Geotechnical knowledge	1	0	5 (17%)	
Prescience	1	0	1 (3%)	

Table 5.3 (above) shows that responses to this question boosts support for hydrology, local knowledge, preparation to 30% or over, and provides additional support for interest in weather forecasting/meteorology and risk assessment.

Responses that received support from nine or more of the total group of respondents (30% of those answering this question), have been outlined in table 5.4 (below):

Table 5.4: Areas of useful skills and knowledge nominated by respondents including additional skills

	Skills and knowledge	respondents
1	‘Risk assessment’	15
2	Weather or meteorological information	14
3	Hydrology	12
4	Risk management	11
5	Experience of extreme weather events or access to people with this experience	10
6	Local Knowledge	9
7	Preparation	9

Suggestions made by respondents regarding the skills and knowledge that they felt to be useful in analysing, planning and managing extreme weather events also support a great deal of the work already developed. The use of ‘experience’, ‘case studies’ and examples of mining sites that have experienced extreme weather seems to be supported in a number of comments in section 2 of the survey (Experience).

Case study examples suggested include: ‘Tom’s Gully’ (Gold mine), ‘Ensham’ (Coal), Leinster WA (Bronzewing/Navigator resources), ‘WA Cyclone Preparation’ (This has led to the possible inclusion of information from the WA report on the impact of Cyclone Bobby in 1995).

Although the steering group has suggested drought is a key extreme weather event, most of the final survey respondents viewed flooding and storms as the primary ‘extreme’ weather events. No mention was made of ‘drought’ conditions. This may be due to the fact that drought conditions are often being experienced at any given time somewhere in Australia, and are not considered to be an event that is out of the ordinary.

Appendix 6: AusIMM Members Interview (notes)

Interview notes from AusIMM online survey respondents who indicated they were interested in being interviewed.

May 2012

28/05/12 - Respondent A - This respondent has managed extreme weather events and has a broad range of experience in different areas of mining industry and regulation. Has experience in Australia and UK between the late 1960s to the present day.

A indicated his view that:

- Flooding/storm events are a critical focus for dealing with extreme weather events as these are the events that overwhelm existing systems and assumptions, more often than not;
- Hydrology very important, but shouldn't be considered in isolation to other key factors such as the direction of wind – provided an example of two cyclone events that took out essential transport infrastructure on the Fortescue Plain. The first incident 'eliminated' 15km (I get the impression that this was a cumulative total rather than a contiguous part of the alignment) and the response was to thoroughly document the damage using a helicopter – at which point engineers used the information to redesign the infrastructure as part of restoring the alignment. However, the second storm event still managed to take out 6km (again I'm not certain that this was contiguous or cumulative) due to the fact that the water was coming from a different direction to the first event – driven by wind conditions;
- There needs to be more expectation that people will read the landscape directly rather than relying on a statistical analysis of rainfall patterns – 'ephemeral' creek lines are not being recognised as significant indicators of where trouble can be expected in extreme weather events. Existing drainage patterns, and other evidence of impact from extreme weather events are not being utilised – or utilised well – in existing planning for infrastructure design or site development;
- There is inadequate understanding of what the phrase 'one-in one-hundred year event' actually means. His explanation is that 1:100 is best understood as a 'one per cent chance that such a design specification would be EXCEEDED in one year" A then translated this to a 25 year period, where the likelihood of an event exceeding the design specification was 20%. His view is that this terminology should be replaced by something that is more quantifiable and which speaks to the type of consequences that arise from the wrong specification being used. Maximum Probable Flood (also referred to Probable Maximum Flood) was suggested as an alternative;
- The lines that are first drawn on the map as part of a mine development proposal (i.e. the tailings dam will go here…the processing plant will go here….) are difficult to change – so it is important to get the appropriate data and risk analysis into the planning BEFORE these lines are drawn. This presents a cost that might seem difficult to justify unless the risks and the scale of the potential impacts are understood in a 'pre-pre-feasibility' process where some of the basic value propositions of a proposal are determined; and
- Works undertaken by consultants are primarily tested against the needs of the client and the interpretation of the relevant regulations – whether the work is going to stand up to scrutiny or an event on the ground is largely untested by a 'peer review' process.

A also provided a wide range of useful new sources of data –

- Coronial inquest into ‘Emu mine disaster’ in WA (1992) – tailings dam situated across the ‘ephemeral’ creek line - start of a disastrous chain; and
- Fitzroy River flooding in WA and the consistent underestimation of risk and impact of interventions.

28/05/12 - Respondent B – This respondent has indicated that they have analysed, planned and managed extreme weather events at mining operations. Has experience of ‘east and west’ mining cultures and circumstances.

B indicated his/her view that:

- A key approach was to ‘know your project’ – i.e. the physical and technical parameters and interactions;
- Current approaches to managing water on mining sites were not necessarily providing better outcomes for companies or the environment – criticised the emphasis on ‘containment’ as the main focus. Directing water to ‘the pit’ should be a ‘worst case scenario’ not the first line of approach due to the fact that the waters on site are of differing qualities and may become more problematic to manage once they’ve been in the pit. More contaminated and more costly to remediate;
- Professionals may lack important information for several reasons including:
    - Differences in relevant departmental capacity to respond to requests for information - example given was the difference between departments that are commonly associated with mining (i.e. primary resources) and those that are not (i.e. departments with responsibility for water systems).
    - Lack of experience of these events
    - Lack of expertise or adequate expertise for analysing potential for consequences (i.e. availability of hydrologists of good standing)
    - Outsourcing of experience and expertise to consultancies; and
- VERY IMPORTANT: Professionals may lack opportunities to make changes if these conflict with existing plan of operation and the environmental conditions that are attached to the plan of operation.

30/05/12 - Respondent C – This respondent has been involved in mining from the late 1960s. Has been a general manager of coal mines in NSW and Queensland. Is involved in emergency services and has experience of extreme weather events through this activity as well as in mining.

Respondent C provided several views about what is important in managing extreme weather events:

- Access to mines is an important matter – some mines have been developed with the historical knowledge of previous events in mind (an example was a family mine that had been sited above levels attained in an 1893 flood). However, in this particular case this pit was still affected by the Qld floods in 2010/11. Despite the interventions that have been made since the pit was developed (the Somerset Dam has been built with a view to reducing flooding to a certain extent) there was still two metres of water in the pit. This flooding was much less of a problem than the flooding of the surrounding area, which limited access to the site and limited the possibility of addressing flood related issues on the site;
- “Flat country is flat country” and there is “always the potential” for flooding to make it impassable if it occurs in a low point of the landscape. Also risks that ventilation arrangements face if they are in a low point in the area or in the path of a drainage feature;

- While cyclonic activity is recognised as a problem, this respondent believed that the ‘rain depression that follows is a serious problem as well;
- Noted an incident in which bore holes can be difficult to identify hazards in flood conditions due to interactions with water pressure developing in confined conditions underground. Cited an incident in which a 4-inch bore hole became a cone shaped hole 10 metres deep and 20 metres across when water pressure developed in mine tunnels and exited via the bore;
- Noted the prevalence of 20/20 vision after the fact and the common view that precautions are viewed as unnecessary expense when “the sun is shining”;
- Noted that there is a great deal of experience available but much of it is retiring and not being incorporated into the knowledge base of new professionals;
- This respondent suggested that much more detailed and site specific modelling be done to identify the risks associated with extreme weather events. Cited his recent experience of using sophisticate computer networks to model explosions in underground mines and considers that this would be useful to undertake with respect to flooding and storms. Commented that explosions are more dynamic and faster than flood and storm events, so this should not present a big problem. Noted that the explosion modelling utilised existing programs and then tweaked and calibrated them using data. Suggested that something similar should happen for extreme weather events;
- Noted that cyclone modelling should be sensitive to the fact that it is not a single vector but made up of ‘micro dynamics’;
- Confirmed other respondents’ view that more attention should be paid to the drainage patterns of the sites (natural and constructed);
- Thought data should also be generated when post-event water releases happen. This should be added to the knowledge that exists regarding the drainage patterns;
- When asked about the extent to which mines are already being successfully evacuated under extreme weather events, the respondent suggested that some systems for avoiding some risks from extreme weather are already well embedded in a number of sites;
- Thought bushfires were also a problem for some mines. Cited 1968 fires in Illawarra region in which miners taking shelter in pit were well protected;
- Important to remember that each site represents a different set of risks and presents different problems in managing extreme weather – detailed knowledge of the site and the surroundings are required; and
- Thought that focussing on the safety of people on or around the site represented a good way to think about risks and implications.

28/05/12 - Respondent D – This respondent has experience of extreme weather events in several international contexts. Significant experience in Arctic area and has formed views about extreme weather events in this situation. Currently translating this experience to a tropical climate.

Respondent D’s views about planning, preparing and managing extreme weather events included:

- The need for as much notice as possible, and high levels of awareness of the precise nature of the extreme weather event – is it a short event? A long event?;
- The need for extensive as possible weather data – historical extreme weather events and impacts, 12 hour, 5 day and seasonal weather patterns, annual trends as well as broader cycles such as El Niño and La Niña;

- The value of local knowledge and experience of extreme weather events held by people with a significant long-term involvement with operations at a particular site.
    - Noted the value of foremen and team leaders with 15 years of experience on the ground in informing analysis of risk levels presented by weather developments;
- The value of having trained weather observers on staff. As the experience of this respondent related to a remote, FIFO, operation the availability of trained weather observers on staff to manage flights enabled them to have a very sensitive early warning system. These staff utilised both aviation data and weather pattern knowledge to interpret conditions;
- Clarity about the type of conditions that should trigger decisions – three levels of threat established with key decisions made depending on the nature of the event. These decisions related to the movement of workers, movement of equipment and the preparation of equipment that will not be moved;
- This respondent used three distinctive timescales:
    - 12 hour (events tended to develop within this timeframe)[not given a name by respondent but 'immediate' might be appropriate?]
    - 'short' - 5 days (regional weather patterns could be monitored along this timeframe)
    - 'long' – annual patterns and trends to aid in preparations;
- Decisions regarding 'pre-positioning' involved using early warning systems to evaluate whether workers in isolated areas needed to be brought in, equipment sheltered or shut down (as appropriate):
    - Well-established practices and procedures, and lines of responsibility for making calls regarding threat level and actions very important;
- Supportive management is very important to having a site that is capable of weathering extreme events without significant negative impacts.
- Key communications with management involved the language of 'safety' 'costs' (lost production, increased maintenance, new equipment) and reducing the time taken to 'recover' from events;
- Recommended use of existing data gathering resources in the area including weather stations, records from any nearby airfields. If none exist then investing in an 'automatic' weather station or two (around 100K each) is a cheap option given the potential impacts. If there are other operations in the area then these costs could be usefully distributed;
- Understanding impacts of different approaches to equipment – example given of preparations for extreme weather - drilling rigs procedure initially consisted of leaving the equipment in place and leaving the engines running to avoid having to lose time in thawing them out after a storm. However, in this incident the winds were strong enough to force snow into air intakes and into the engines, which began a chain of events that resulted in sump seals rupturing, and the engines being destroyed. Procedure now specifies turning the engines off and the use of heating equipment to warm up the components to the point where they can safely operate again. Takes less time and costs less than replacing the equipment.

Confirmed other respondents' views:

- Knowledge of the broader situation surrounding the site, including the physical, social and community aspects of the local area in which the site operates is very important to understanding the risks and potential impact of an extreme weather event;

- Frequency and impact of extreme weather events are important to understand; and
- Reading the environment is important– in this case long-term association with the area allowed some mine site personnel to very successfully read the weather.

Appendix 7: AusIMM Bulletin Article (February 2013)

Planning for extreme weather: lessons from Queensland

By Leah Mason and Dr Damien Giurco (MAusIMM), University of Technology, Sydney.

With the losses experienced by industry and the broader Australian community during last year's flooding and storm events, members of the public, governments, finance and insurance industries are putting greater focus on adequate preparation. Meeting the expectations of these stakeholders is an important part of maintaining social licence to operate, which gives mining and mineral professionals key roles in developing and implementing plans for extreme weather preparedness. Analysing the risks of extreme weather events and changes to local climatic conditions are an important part of risk analysis for an increasing number of operations.

Australia is a dry continent whose climate can vary significantly across months and decades. Whilst planning for extreme rainfall in PNG or Indonesia may be top of mind, the prolonged drought which occupied much of the last decade in many parts of Australia, put a *lack of water* – rather than too much water – as a key concern in the minds of many, including mine operators. Reduced availability of water for use in production had been a rising challenge for Australian mining operations, while long periods of higher temperatures can affect the reliability of electricity supply, the productivity of workers and the functioning of equipment.

However, as recent events last year in Queensland, NSW, and WA have shown, the impact of extreme weather events on operations and distribution of minerals can be enormous. Losses related to the floods in Queensland were evaluated at $30,000 million. Losses to the mining industry alone have been estimated at $2,500 million (Easdown, 2011).

Review of impacts

While extreme events have been planned for at mines, the actual extent and costs of damage has not been accurately predicted. Costs and losses have been large, and return to production has taken many months. The final report on flooding in Queensland during December 2010 and January 2011 noted that 85% of Queensland coal mines restricted production or closed entirely as a result of the extended rainy weather. Five months later, this sector was operating at 75% of pre-flood production (Queensland Floods Commission of Inquiry 2012).

Direct impacts from flooding and storms can occur when flooding or storms damage equipment, infrastructure, and personnel. Damage to personnel and equipment can take place when:

- Storage and accommodation areas are built in areas where water will build up, or travel through at high speeds, under storm or flooding conditions;
- Mine pit flooding, with dirty water then needing to be safely pumped out; and
- The design specification of water storage on site is lower than is required, resulting in the mobilisation of additional water, contaminants and physical hazards from dislodged and damaged structures.

Indirect impacts from flooding and storms also need to be considered. Indirect impacts can arise as a consequence of direct impacts and post-flooding impacts, and may include:

- Lost productivity due to damaged or unavailable equipment;
- Loss of reputation based on the perception that preparation or management systems were inadequate;
- Lost business due to reduced production; and
- Increased costs for ongoing operations in the aftermath of flooding (measures to limit or eliminate damage from de-watering processes, and monitoring of local water resources)

Learning to read the landscape

Following on from a survey in Week-in-Review, several AusIMM members – with over 100 years of experience of extreme weather events between them – were interviewed by the authors to share their experiences. While these members had worked in different parts of the world, as well as Australia, each clearly expressed the need for mining and mineral industry professionals to “know their site” and to develop skills in “reading the physical landscape” around them.

Key points raised by these professionals focussed on the need to go beyond “hydrology” and “statistical analysis of rainfall patterns”, to other key factors in assessing the risks of extreme wet weather events. This included:

- The impact of wind direction on flooding impacts
- Micro dynamics of cyclone events
- The impact of rain depressions that follow cyclonic events.

There was also agreement that mining and mineral professionals need to be able to “read the landscape” using the widest range of information that is available. This can come from a careful assessment of:

- ‘Ephemeral’ creek lines (significant indicators of where trouble can be expected in extreme weather events);
- Existing drainage patterns (man-made and natural), and other evidence of impact from extreme weather events - particularly when planning infrastructure design or site development; and
- Drainage dynamics and impacts when post-event water releases happen.

A further point made by those interviewed, was that this type of information should be gathered and analysed early, preferably before the site facilities are constructed. If not, it may be difficult to address risks where changes conflict with existing plan of operation and the environmental conditions that are attached to the plan of operation.

Awareness of changes to the weather across short (12 hour forecasts), medium (5 day and seasonal forecasts) and longer-term (annual trends, broader cycles such as El Niño and La Niña) provide the best forewarning of significant events, and provide the best information about the precise nature of an extreme wet weather event. Documentation of impacts from historical events can also be very useful.

Additional data gathering resources suggested by those interviewed included local weather stations, and records from any nearby airfields. If there are no local weather stations in the area, then investing in an 'automatic' weather station or two (around $100,000 each) is a worthwhile option given the potential impacts.

For example, more than a year after the floods, there is still about 250 to 300 gigalitres of excess water sitting in mines in Queensland or about half of the volume of water in Sydney harbour (ABC News, 2012).

This article is based on a chapter of forthcoming best practice guidelines to planning for extreme weather and climate adaptation being developed by researchers at UTS with support from AusIMM and NCCARF.

Thank you to the AusIMM members who took part in the research.

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