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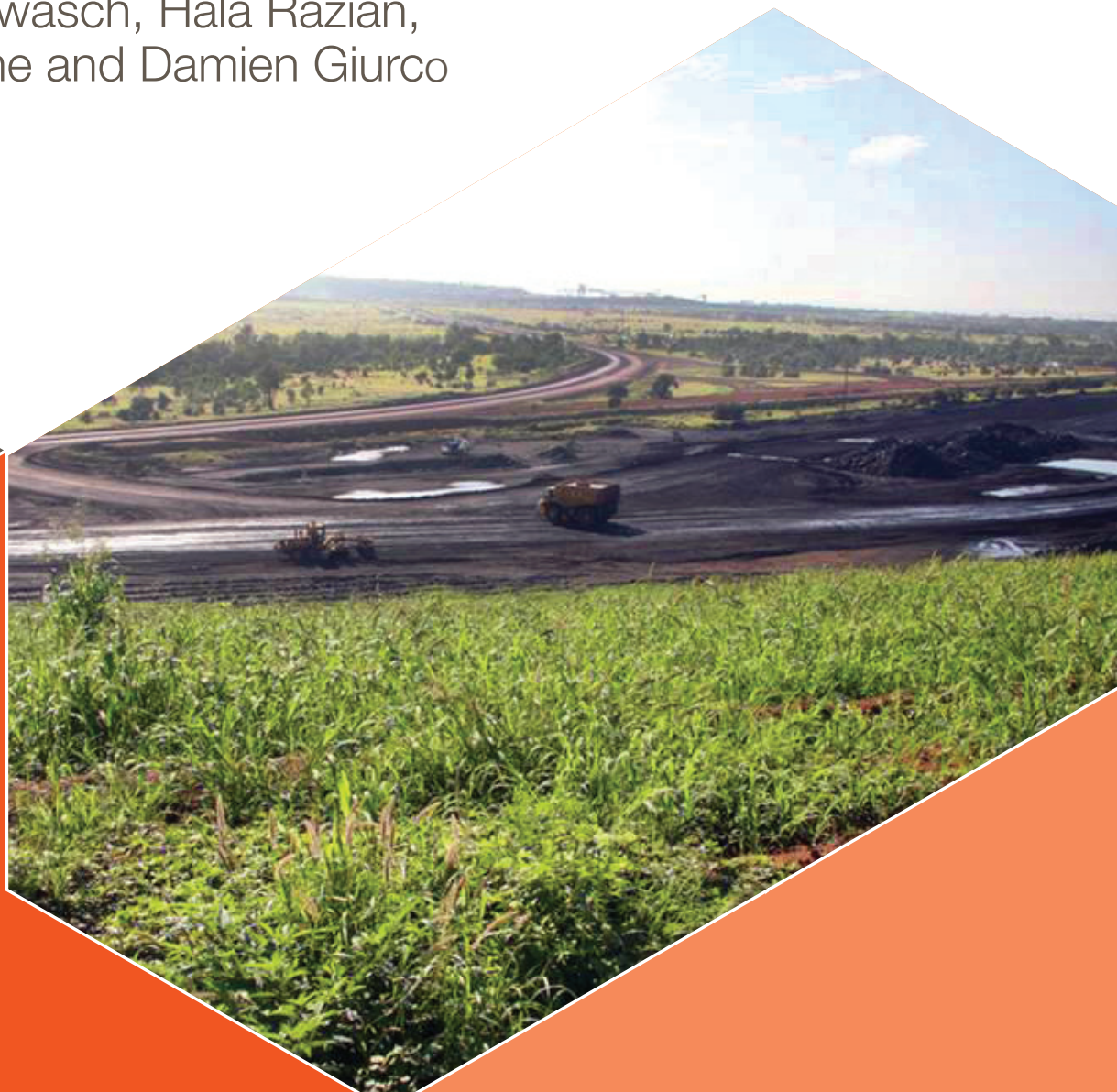
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Adapting to climate risks and extreme weather: a guide for mining and minerals industry professionals

Leah Mason, Corinne Unger,
Aleta Lederwasch, Hala Razian,
Laura Wynne and Damien Giurco



ADAPTING TO CLIMATE RISKS AND EXTREME WEATHER: A GUIDE FOR MINING AND MINERALS INDUSTRY PROFESSIONALS

Institute for Sustainable Futures
(University of Technology, Sydney)

Authors

Leah Mason (University of Technology, Sydney)
Corinne Unger (The University of Queensland)
Aleta Lederwasch (University of Technology, Sydney)
Hala Razian (University of Technology, Sydney)
Laura Wynne (University of Technology, Sydney)
Damien Giurco (University of Technology, Sydney)



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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.

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1 INTRODUCTION

1.1 Why this guide?

Whilst mining and mineral professionals have experience with risk management and managing workplace health and safety, changes to patterns of extreme weather events and future climate impacts are unpredictable. Responding to these challenges requires planning and preparation for events that many people have never experienced before. With increasing investor and public concern for the impact of such events, this guide is aimed at assisting a wide range of mining and mineral industry professionals to incorporate planning and management of extreme weather events and impacts from climate change into pre-development, development and construction, mining and processing operations and post-mining phases.

1.2 Using this guide

As the situation of every mining and mineral production operation is going to be different, this guide has been designed to provide general information about the nature of extreme weather events, and some specific examples of how unexpectedly severe flooding, storm, drought, high temperature and bushfire events have affected mining and mineral processing operations. A number of case studies used throughout the guide also illustrate the ways forward thinking operations have tackled dramatically changing climatic conditions.

Each section of the guide outlines a range of direct and indirect impacts from a different type of extreme weather, and provides a starting point for identifying potential risks and adaptation options that can be applied in different situations. The impacts and adaptation sections provide guidance on putting the key steps into practice by detailing specific case examples of leading practice and how a risk management approach can be linked to adaptive planning.

More information about specific aspects of extreme weather, planning and preparation for the risks presented by these events, and tools for undertaking climate related adaptation is provided in Section 5 Additional Resources.

2 CHANGING CLIMATE AND EXTREME WEATHER: THE BUSINESS CASE FOR PLANNING AND PREPARATION

With the personal and financial losses experienced by Australians during recent flooding and storm events, it is not surprising that key stakeholders in mineral development, such as governments, insurers, institutional investors, and members of the public are focused on avoiding such losses in the future. Mining and mineral professionals have key roles to play in meeting the changing expectations of these stakeholders by ensuring that operational responses to these events are well-grounded in leading practice and current information. As changes to historical climate conditions open up new areas of risk, this guide outlines how these risks can be incorporated into a more comprehensive framework of environmental and socio-economic risk-identification, risk-management, as well as sustainability and workplace health and safety practices.

2.1 Changing climate-related risk

Australia is a dry continent, but it is also subject to significant variability, with some decades being much wetter or dryer than others (BOM, 2012). As recent events 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 2010-11 floods in Queensland were evaluated at \$30,000 million. Losses to the mining industry alone have been evaluated at \$2,500 million (Easdown, 2011). Measures of costs to reputation and costs from new legislative requirements imposed on industry, due to environmental impacts from significant releases of polluted water from mines, are less easy to quantify (QFCI, 2012). Often omitted in costs estimates are the human health and environmental health impacts from such floods. Less spectacular than flooding and storms, but equally important, are the 'extremes' associated with droughts and increased temperatures. Changes to the availability of water for use in production have 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 (onsite and DIDO/FIFO) and the functioning of equipment. Long-term trends for rainfall, sea levels, average maximum temperatures, and storm activity are showing that extreme weather events are likely to be even more severe than they have been in the past. Rainfall variability and temperature extremes also impact the success of progressive mine rehabilitation programs, and affect tailings dam design and long-term closure planning.

2.2 Changing costs

Changing costs are already a part of the Australian mining and mineral processing business environment. For example, mining and mineral professionals are already active in adapting to increasing costs from changes to available ore quality and mineralogy, labour costs, and in responding to changes to regulations around water availability, and energy supply. Increasing frequency or severity of extreme weather events will require adjustments to assumptions about risks, risk management, and entail the redesign of existing infrastructure (i.e. tailings containment). As professionals working in mining and minerals processing – a shared understanding of changing risks and options will help in long-term planning which delivers community and shareholder value. 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.

2.3 Changing risks for stakeholders

The severity of recent extreme weather events in Australia has already shown that mining and mineral processing operations can be a source of increased risk 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. Ensuring that risks from changing climate are identified and managed responsibly, at all times, provides reassurance that broad ranges of concerns about potential impacts are being taken seriously.

3 FLOODING AND STORMS

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 than it is 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 in the area (CSIRO 2007 updated 2011). 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 that 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.

The Queensland floods have also illustrated the complexities of managing water under different conditions. 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 during drought conditions. However, having a maximum capacity of water stored on site at all times can increase the risks to the site and to communities or businesses downstream when drought turns to flood (QFCI, 2012).

3.1 Risks and Impacts

Risks and impacts from flooding and storms can be direct, indirect, or a combination of both. Where an operation is one amongst many in a particular catchment, assessing and managing risks and impacts may only be possible through cooperation to avoid issues that arise from cumulative impacts. Some risks and impacts can also occur at a considerable distance from mining and mineral processing operations. An overview of each impact type 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 areas are built in areas where water will build up, or travel through at high speeds, under storm or flooding conditions; 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. Striking examples occurred in Baia Mare, Romania (heavy rain and melting snow) and more recently the Timfoldgyar red mud dam failure in Ajka, Hungary.

Impacts for productivity can occur when large volumes of water make open pits and/or underground mine systems inaccessible, and/or equipment unusable. This lost productivity may also result in costs where contracts cannot be met, and lost business where production cannot be reinstated for long periods.

Loss of reputation, based on a perception that preparation or management systems were inadequate is another area where flooding and storms can have a very significant direct impact.

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:

- Costs and impacts of managing large volumes of contaminated water over long periods; and
- Breaches of regulations or conditions of consent that occur as a result of impacts at multiple sites, within a catchment, including:
 - Increased costs for ongoing operations in the aftermath of flooding including measures to
 - Limit or eliminate damage from de-watering processes
 - Repair eroded waste rock/spoil landforms
 - Monitor of local water resources
 - Long-term closure planning programs.

Impacts at a distance can occur when operations are reliant on people, facilities, services, or materials that are being affected by flooding and storms happening elsewhere. Again, cumulative effects from one or more operations can increase the impact of flooding and storms on communities downstream of the mining region.

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 and projections based on long-term trends;
- 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 the measures are as appropriate as they can be.

The information and case studies that follow illustrate some of these risks and the impacts of inadequate assessment or management of such risks. Measures to avoid or adapt to changing conditions, and key concepts for understanding weather and climatic variability are provided at the end of this section.

3.2 Flooding and storm case studies

3.2.1 Flooding Case study 1.1: Ensham Mine

Location: 40 km east of Emerald, Queensland,

Mine type: Open cut

Mineral: Thermal Coal

Operator: Idemitsu Australia Resources Pty Ltd

The Ensham mining operation includes six open pits, administration, workshop facilities and on site workforce accommodation camp. Additional supporting infrastructure onsite are a coal processing plant, a rail loop and train-loading facility. Coal is transported to the Port of Gladstone to international and domestic customers.

Flooding resulting from an “unprecedented combination of floodwaters from the Theresa Creek and Nogoia River systems upstream of Ensham, together with flood releases from Fairbairn Dam” (Ensham, 2008) during early 2008 filled two of six pits with 150 GL (gigalitres) of water (Delzoppo,

2011). Existing planning for flooding at the site anticipated a “one-in-one-hundred-year event”, but the scale of the actual event was much larger. Peak flow around the mine was estimated at 250 GL/day (Delzoppo, 2011).

Immediate impacts:

- Levy banks were either over-topped or breached (Delzoppo, 2011);
- Production halted (Porter, 2008), and \$100 million equipment was entirely submerged by floodwaters (Lewis, 2010);
- Floodwaters in pits required release into Nogoa River (Delzoppo, 2011);
- Internal haul roads and light vehicle access roads were destroyed (Feary, 2008); and
- Employees had to be evacuated (Porter, 2008).

Longer-term impacts:

- Salinity of released floodwater affected domestic/drinking water quality for the local community (Delzoppo, 2011);
- 60 GL of water had to be purchased from Fairbairn Dam to dilute water transferred from pits to local streams (Delzoppo, 2011);
- Many employees were unable to return to their usual work for several months (Porter 2008);
- Dragline was not recovered for 4 months (Lewis, 2010);
- Production stopped for 6 months, and return to full production did not occur for 12 months (Porter, 2008);
- Monitoring and reporting of floodplain and river conditions now required at two year intervals (to state government) (Re Idemitsu Australia Resources Pty Ltd & Ors, 2010);
- The 2010/2011 wet season (including flood events) added 11,000ML to the existing 9,000 ML of water remaining from 2008 flooding (Westerhuis, 2011); and
- Monitoring and reporting on condition of several bore water sources (to local landholder) (Re Idemitsu Australia Resources Pty Ltd & Ors, 2010).

The bottom line:

- Total damages were reported by the company as being \$270 million in May 2008 (Porter, 2008); and
- Total costs were estimated at over \$300 million by July 2008 (Feary, 2008).

Adaptation actions and options:

- Retrofitting of operations by building new levee banks to withstand a similar flood event (characterised as a “one-in-1,000 year” flood event);
- Upgrading of catchment diversions as no creek diversions were proposed in EIS (Qld EPA, 2006); and
- 2010/2011 flooding blocked access to the site prompting the company to investigate options to build a single lane bridge above the most recent flood level (Westerhuis, 2011).

3.2.2 Flooding case study 1.2: Baralaba Mine

Location: near Baralaba, Queensland,

Mine type: Open pit

Mineral: PCI coal and thermal coal

Operator: Cockatoo Coal Limited

Baralaba mine is an open-pit operation, managed by Cockatoo Coal Ltd with blasting, mining and haulage services provided by contractors. Crushing and screening of coal mined from different seams is also undertaken on site. All the coal sold is exported from the port of Gladstone, which is located 225 kilometres from the mine operation. Baralaba was one of several mines affected by

flooding that occurred in Queensland in late December 2010. Heavy rainfall in the weeks leading up to the severe flooding events had already affected local rivers, limiting access to the site and restricting transport of coal to port facilities. Facilities such as administration, processing and workshops were on high ground and were undamaged.

Immediate impacts:

- Raw coal production was stopped for 4-5 months.
- Flooding also restricted exploration activities

Longer-term impacts:

- Full production resumed by Q3 2011

The bottom line:

- No dividend was paid for the financial year ending 30 June 2011.
- Operating losses for Cockatoo after income tax was \$21,906,880 (compared to 2010 profit of \$3,517,569).
- Operating losses have resulted in material uncertainty about the Group's ability to continue as a going concern.

Adaptation actions and options:

- Cockatoo Coal was required to retrofit levee banks to withstand a one-in-1,000 year flood - approximately 2.5 metres higher than the 2010 flood event.

Sources: Cockatoo Coal Limited (2011, 2012)

3.2.3 Flooding case study 1.3: Yallourn Coal Mine

Location: Victoria

Mine type: Open pit

Mineral: Coal

Operator: TRUenergy

The facility at Yallourn includes Australia's largest open cut coal mine, which supplies the nearby Yallourn power station.

Heavy rainfall in early June 2012 caused the artificial banks on a diversion of the Morwell River across the Yallourn Mine to collapse (Gardiner, 2012; EPA Victoria, 2012). Flooding from the damaged diversion damaged conveyor equipment and diverted water collected in open cut mine. Production at the mine was significantly reduced, impacting on the capacity to generate power at the Yallourn power station. This station, which supplies 22% of the State's electricity, was reduced to using only one of four power generation units for a period of two weeks, before a second unit could be brought back online with repairs to conveyors. However, only three weeks after the initial collapse, further heavy rainfall caused delays to repairs and reduced generation capacity to a single unit again (Energy Australia, 2012a). Throughout this period, the mine required an approval under the Victorian Environmental Protection Act to pump water from the mine site to the nearby Latrobe River (Victoria EPA, 2012). Approval conditions for pumping required testing for temperature, pH, suspended and total dissolved solids, turbidity, colour and salt levels three times a week for at eight sites, and analysis of metals and nutrients once a week for the period covered by the approval (120 days) (Victoria EPA, 2102). Three months after the initial collapse, recovery work on the river diversion was estimated to take eight months to complete (Energy Australia, 2012b).

Immediate impacts:

- Damaged coal conveyors (ABC News, 2012)

- Flooded mine (ABC News, 2012)
- Reduced electricity output to 25% of full capacity (ABC News, 2012; EPA Victoria, 2012)
- Company forced to apply to EPA for emergency approval to pump flood water from the mine (EPA Victoria, 2012).

Longer-term impacts:

- River diversion restoration – estimated to take eight months (Energy Australia, 2012b)
- Full mine production capacity not restored
- Full electricity generation estimated to be 6 months after initial collapse (Song, 2012), but capacity not yet restored

The bottom line:

- Estimated financial impact of the Yallourn mine flooding to CLP Holdings nominated as \$109 million by the end of June 2012 (Song, 2012).

Adaptation actions and options:

- Consider public planning and consultation regarding adaptation strategies as part of the ongoing social licence to operate for the mine.

3.2.4 Flooding case study 1.4: Fimiston Open Pit (Superpit) Mine

Location: Kalgoorlie, 550 km east of Perth, Western Australia,

Mine type: Open pit

Mineral: Gold

Operator: KCGM Pty Ltd for joint venture partners, Newmont Australia Limited and Barrick Gold of Australia Ltd.

This mine is known as the largest open pit gold mine in Australia. Ore is mined as a truck-and-loader operation, and treated at the Fimiston mill. Sulphide concentrates are then roasted and leached at the Gidji roaster, located approximately 20 kilometres north of the main Kalgoorlie operations.

Unlike many of the flooding events that have affected mining and mineral processing operations in recent years, the issues at Fimiston are chronic occurrences (Environ Australia, 2006), and create distinctive risks. For example, the impact of heavy rainfall, averaging about 21 mm per month and up to 31.6 mm per month (BOM, 2012) between January and August, has both on-site and off-site consequences, and each represents a different type of risk. A key risk to operations at the mine is the effect of long-term exposure of geo-technical engineering works and equipment to water. Recent examples of this impact occurred in January, June and in October of 2011, when periods of continued rainfall and severe storms caused a rock-fall event. Although site personnel were not injured in this instance, there was damage to portions of the mine (KCGM, 2011a,b,c). In contrast, a risk to both the economic viability of the site and its 'social licence' to operate, are the impacts that constant pumping of water from the mine site have on the quality of the local power transmission system.

Immediate impacts:

- After a rock fall event, access to affected areas is restricted, pending a geotechnical review (KCGM, 2011b), resulting in an immediate loss in productivity; and
- Constant pumping of water to provide access to minerals in open pits affects power quality at the site and in a local township (Hodgkinson et al. 2010).

Longer-term impacts:

- A comparatively fast process of groundwater recharge, following significant rainfall events has resulted in an accumulation of surface water, and the development of a “water mound” beneath site facilities’ and
- Over time, poor power quality has reduced equipment life at the mine site and in the local township, and this potential could cause loss of good will in local stakeholders.

Adaptation actions and options:

- Management of the abovementioned water mound occurs through a “Seepage and Groundwater Management Plan (SGMP) (Environ Australia, 2006 p.53)
- Improvements to the transmission system (or additions through generators or wind/solar generation systems) present several additional methods for meeting increased energy use without risk of further declines in power quality. Successful adaptation will have a significant impact on operations and on the good will of local communities.

Further sources: <http://www.mining-technology.com/projects/superpitgoldmineaust/>; Hodgkinson et al (2010), <http://www.superpit.com.au/AboutKCGM/Overview/tabid/88/Default.aspx>

3.3 Case study discussion

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, as with case studies 1.1 to 1.3, 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. Even in areas where such events are routine, such as in case studies 1.4, it is still possible to under-estimate the effects and the risk posed.

In all case studies, the 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. Several of these case study mines have now considerably increased their assessment of the risk posed by these events, and have now:

- Identified a one-in-one-thousand flood scenarios as appropriate to risk assessment and management; and
- Re-designed key infrastructure to address extreme weather events of this magnitude

Case study 1.4 illustrates the problems that come with increased energy requirements that are necessary to operate under wetter than average conditions.

3.4 Anticipating disastrous change: international examples of adaptation options

Success in reducing or eliminating such risks will require damage and risk mitigation procedures that incorporate heavy rainfall and flood into operational models. Identifying hazards presented by the interaction of daily, seasonal and once-in-a-lifetime events, require a good understanding of site positioning, local flooding history, daily and seasonal weather patterns, and long-term trends. Several case study mines have illustrated the value of taking action to avoid or limit risks and impacts, while a range of international examples of mining and mineral processing operations provide further guidance to adaptation options that may also be worth exploring in the Australian context. The following examples are taken from Nelson and Schuchard (2011).

Incorporating changes to climate conditions into existing processes

- Examples of mining and mineral processing businesses that are modifying existing risk identification processes include “Norsk Hydro, which incorporates climate change risks into its standard social and environmental risk assessment processes”; Anglo American, which

has plans to integrate a “climate test” into its capital- expenditure approval processes, 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”. Climate criteria are also being incorporated into a new standard for mergers, acquisitions and divestments

Developing or using existing models to assess likely risks and impacts

- Companies using models of climatic conditions, or using data on the probability, magnitude, and frequency of extreme weather events are increasing their awareness of likely impacts and improving their capacity to mitigate or eliminate the risks. For example Exxaro is using downscaled general circulation models to assess impacts for mine sites and for communities where employees are located. Kumba Iron Ore is using data on extreme weather events to calculate impact on site structures over many years, and Anglo American is using site level data on temperature and rainfall to create a “risk inventory” and specific site adaptation strategies (Nelson and Schuchard, 2011).
- 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 (Hodgkinson et al 2009).

Examples from Nelson and Schuchard (2011) 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;
- Norsk Hydro, which is raising its facilities in Qatar by two meters to withstand flooding; 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 storms in time to shut down and secure equipment.

Actions such as those outlined above, and in the following sections, will help to manage and potentially reduce insurance premiums, workplace health and safety disputes, damage to company and neighbouring property, as well as legal damages claims. Effectively anticipating and mitigating risks, will also contribute to maintaining a social license to operate at a time when environmental concerns around mining have become a critical issue for Australian mining.

3.5 Looking to the future: long-term trends for flooding and storms

Having explored case studies and adaptation options in the areas of flooding and storms, historical data regarding long-term trends for climate variables like sea level and rainfall are a useful place to begin identifying where existing systems might need to be reassessed within future risk management processes. A key point in interpreting the impact of changes to sea levels, storm and flooding events, rainfall more generally and temperature, is that there are significant interactions between them. For example, the direction, timing and ferocity of wind patterns can make a very big difference to the impact of storm surges and flooding.

3.5.1 Sea-level rise, storms and flooding

Local sea level is an important part of understanding the potential impact of storms for operations on or near the coast. A major concern related to rising mean sea level is the increased risk of damaging storm surges. A storm surge is an unusually high tide caused by a combination of falling

pressure and intense winds during extreme weather events such as tropical cyclones (CSIRO 2007). Figure 3 shows the relationship between mean sea level and the storm surge height.

3.5.2 Long-term trends in sea-level rise

The National Tidal Centre has been monitoring sea level changes and notes the future potential for “abnormally” high sea levels to “cause flooding, coastal erosion and property damage,” (National Tidal Centre 2011). Figure 1 shows the trends in local sea-rise at different points around Australia between the early 1990s and 2010.

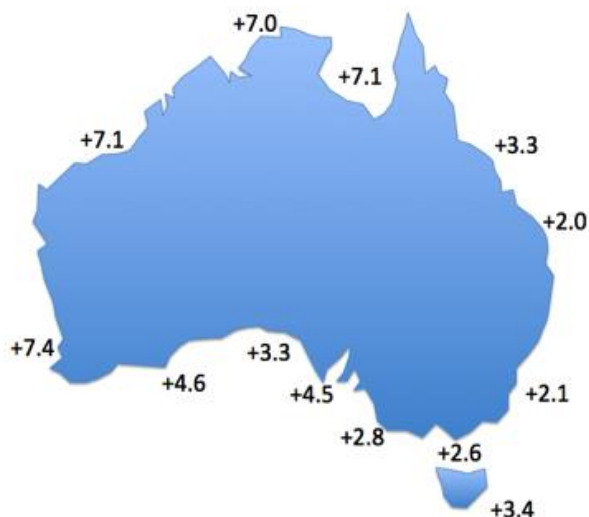


Figure 1: Tidal rises between early 1990s and 2010 (Adapted from DECC 2011)

As shown in Figure 1, The National Tidal Centre’s observations of long-term trends for local sea-rise changes are as high or significantly higher than it was between 1961 and 2003, when the average rate was 1.8mm per year (± 0.5 mm). Global and regional estimates in some areas. While these rises may be perceived to be small, even small changes to sea level are still likely to amplify seasonal events such as king tides, storm surges, as well as less frequent extreme weather events such as cyclones or extended periods of rainfall which cause flooding (National Tidal Centre, 2011).

Risks identified: Given that a large proportion of Australian infrastructure including commercial and light commercial buildings, roads and railways are close to the coast (DECC 2009, DECC 2011) it is likely that the infrastructure needed by mining and mineral processing industry will be adversely affected by sea-level rise. For example, a recent assessment of key coastal infrastructure indicated that assets at risks in Australia from the combined impact of inundation and shoreline recession include between:

- 5,800 and 8,600 commercial buildings, with a value ranging from \$58 to \$81 billion*
- 3,700 and 6,200 light industrial buildings, with a value of between \$4.2 and \$6.7 billion*
- 27,000 and 35,000 km of roads and rail, with a value of between \$51 and \$67 billion*.

These risks should be assessed in combination with information about changes to storm activity and flooding potential of important sites.

*2008 replacement value

3.6 Key concepts for sea level rise and coastal storms

3.6.1 Thermal expansion of water and sea level rise

At present rises in sea level are explained by the expansion of water as it gets warmer (thermal expansion), and the addition of water from melting glaciers and ice sheets (Carter et al 2007).

Importantly, the amount of heat, and the amount of expansion in a given area, will be influenced by local conditions such as ocean currents and spatial variations in ocean warming (CSIRO 2007 p92). Importantly, rising sea temperatures also have impacts beyond changing density of oceans. A higher sea temperature can provide increased energy for a storm or tropical cyclone. The potentially devastating effects of this were seen in evidence with the post-tropical hurricane Sandy in the US, which was fuelled by sea temperatures which were 3-5°C higher than average.

3.6.2 Understanding sea level, storm surge and flooding

As shown in Figure 2, when the mean sea level rises, so too will the height of the storm surge, creating the potential for storm surges to intrude further inland than has previously been the case. When assessing risks, it will also be important to evaluate the influence of wind strength and direction (relative to the coast), as well as the movement of storm systems.

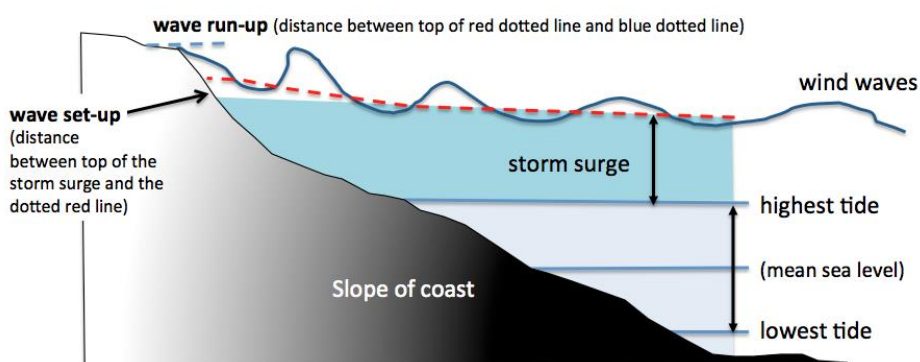
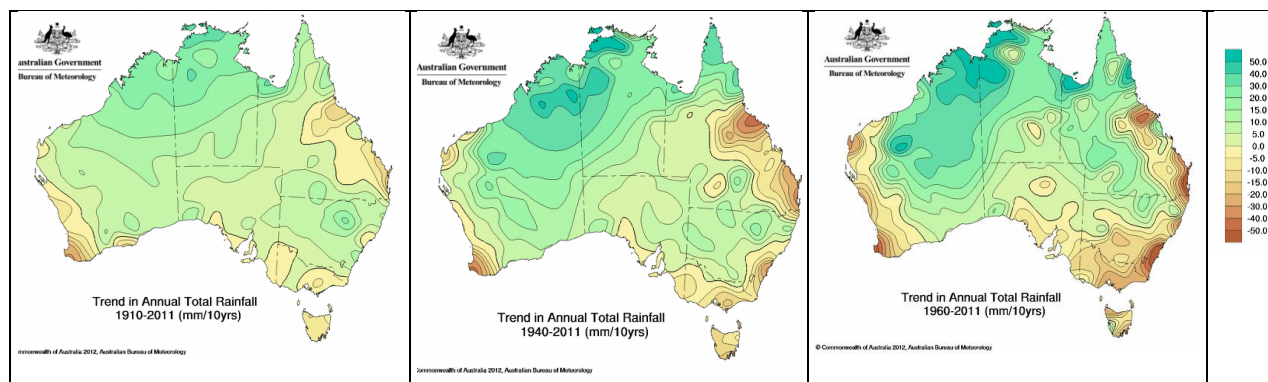


Figure 2: Illustration of storm surge (Adapted from CSIRO Climate Change in Australia 2007 Box 5.2, p94)

3.7 Rainfall, storms and flooding

3.7.1 Long-term trends in rainfall

Over the past hundred years, Australia has already adapted to changing rainfall patterns as shown by the variation illustrated in Figure 3.



Source: Maps of Average Climate, Bureau of Meteorology, Australia. © Bureau of Meteorology

Figure 3: Changes to Australian Annual Total Rainfall 1910-2011 (left) and 1940-2011 (centre) and 1960-2011 (right)

Figure 3 shows changes in rainfall patterns between 1910 and 2011 varied across the continent. In northern Australia, annual rainfall increased significantly, while in most of southern WA, Tasmania, much of Victoria and southeastern Queensland annual rainfall totals declined throughout the century. These trends are marked by intensification in the later part of the century.

3.7.2 Impacts from changes to rainfall

These observations are broadly aligned with the Intergovernmental Panel on Climate Change (IPCC) projections based on global data shown in Figure 4, which indicates a global intensification of tropical rainfall and a drying trend in many continental sub-tropical regions. In some parts of Australia, the projections vary dramatically (e.g. Northern Territory – wetter in (a) and drier in (d)). However, for the area around Perth the trend is consistently drier.

Rainfall is also likely to become less reliable in future years. Changes to rainfall reliability have already been observed and modelled by CSIRO and BOM. Rainfall reliability is an important climate variable for agricultural industries which depend on seasonal rainfall for crops and land management and could intensify competition for water with mining in areas of industry co-existence.

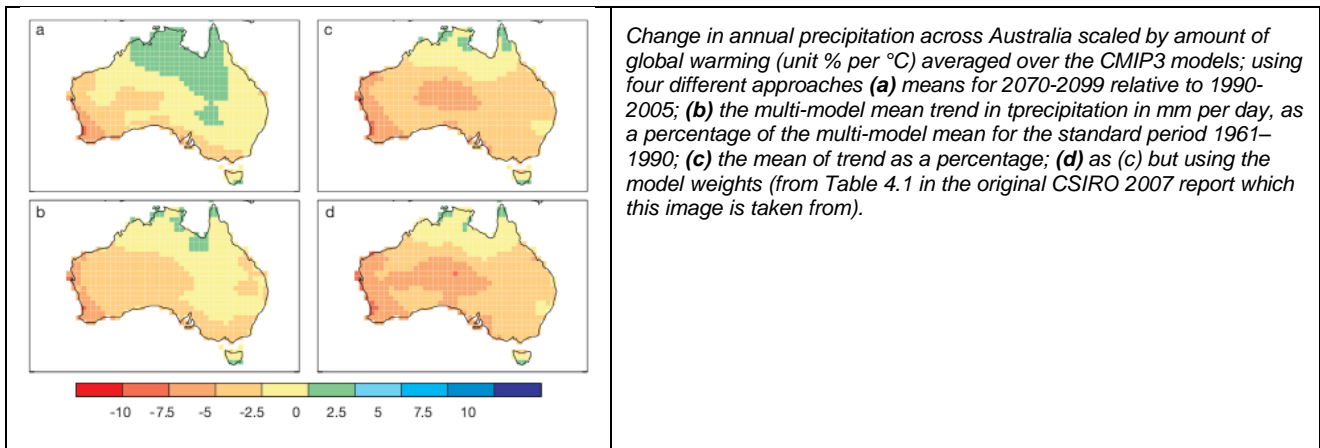


Figure 4: Changed precipitation projections with climate change (CSIRO 2007; Fig 5.14 in original report)

Implications: In areas of declining rainfall, securing water for mining and minerals processing will become more difficult and competition with agriculture in areas of land use conflict could intensify. In areas where rainfall is expected to increase, assumptions about the adequacy of planning for storms and floods may need updating.

Risks identified:

Slope stability can be threatened by fast floodwaters flowing through or around a mine. Erosion and undermining of the toe of a slope can cause rock falls, landslips or debris flows that can create additional damage.

Surface loading caused by extreme flooding over an underground mine may also be of concern. Increased overland flow may also produce flooding potential of underground pits. “If future groundwater levels are going to be different, mine design modelling must consider this.” (Hodgkinson et al 2010, p.10)

4 FEATURE: FLOODING AND ABANDONED MINES

4.1 Issues and challenges of managing abandoned mines during flooding events

More than 50,000 abandoned mine records have been identified in Australia (Unger et al, 2012), some of which present significant problems under extreme weather events. Although many of these mines met government standards of the time (Pearman, 2009), a site where mining leases or titles no longer exist, and responsibility for rehabilitation cannot be allocated to any individual, company or organisation responsible for the original mining activities (MCMPR/MCA 2010), becomes the responsibility of state and territory jurisdictions in Australia, or individual landholders.

In the aftermath of significant flooding events, such as those that have occurred in Queensland between 2010 and 2013, it is increasingly likely that those sites which generate AMD (Acid and Metalliferous Drainage) will create greater impacts and receive more attention. For example, due to the combined impact of improved seepage interception over many decades combined with 2011 and 2013 extreme rainfall conditions, the Mount Morgan open cut pit (containing AMD) overflowed in an uncontrolled discharge to the Dee River in the Fitzroy River catchment, during January/February 2013 for the first time (Townsend, 2013).

Despite being the current responsibility of governments, abandoned mines influence the community perception of the mining sector and its ongoing social license to operate. Where abandoned mines are unsafe, unstable, polluting and/or unsustainable they impact the community perception of the mining industry and the capacity of governments to provide effective regulatory controls to protect communities and the environment from harm.

4.2 Extreme rainfall and abandoned mines

Extreme rainfall events and extended cycles of above average rainfall can exacerbate abandoned mine impacts. These include;

- Infrastructure and safety hazards due to collapse or destabilisation of underground workings causing subsidence, or failure of tailings dams;
- Where landforms are unstable and insufficient vegetation cover exists, erosion and mass movement risks onsite and sedimentation offsite;
- Environmental and human health risks due to direct discharge of contaminated water from open cut pits and tailings dams via overtopping, or seepage through dam or pit walls as well as transportation of acid and metalliferous drainage (AMD) and other chemicals onsite, to waterways impacting biodiversity;
- Land use risks by limiting agricultural land and water uses in the areas impacted;
- Litigation risks; and
- Negative community perceptions of mining and governments which can be directed toward the current mining industry, coal seam gas or other resource extraction activities.

There are a number of ways in which abandoned mines can be managed and rehabilitated to minimise the safety, environmental and socio-economic impacts of flooding.

4.3 Solutions at different scales

4.3.1 Site level management

The Mt Oxide mine site (see Box 2) is covered by exploration tenure and further mining of this site provides one option to address acid mine drainage (AMD) pollution at this site¹. In the absence of that solution, four steps were outlined (Laurence in the Queensland Flood Commission Inquiry 2012), and could set a standard for sites in the care of the QLD government. They are; 'collection

¹Savage River example in Tasmania. see the Goldamere Agreement
<http://www.ausimm.com.au/publications/epublication.aspx?ID=976>

of data and information, risk assessment, decision as to priority and decision as to rehabilitation works' These four steps have been outlined and expanded in Box 1.

Box 1: Abandoned mine site management steps (based on QFCI, 2012)

1. "Collection of data and information" such as:
 - a. Hydrological studies to gain an understanding of surface and ground waters, with early warning monitoring systems (stream hydrology and key water quality indicators such as pH and EC) and modelling to predict future trends and the potential for extreme events,
 - b. Geotechnical studies to investigate stability and competency of any pit walls, tailings dams or levees
 - c. Characterising the waste material present on the site
 - d. Evaluating the mine for potential reopening.
2. "Risk assessment"
3. "Decision as to priority" - such as referring to environmental standards, consistent with community expectations and reflected in legislation for active mines at state and national level
4. "Decision as to rehabilitation works";
 - a. Controlling the source of the contamination, e.g. by sealing underground mines, storing wastes away from rain water or solidifying or encapsulating wastes, constructing covers and revegetating them with sustainable ecosystems,
 - b. Controlling the movement of the contamination away from the mine, e.g. by using biological measures such as wetlands,
 - c. Controlling the amount of rainfall that runs off from the abandoned mine into creeks, e.g. by revegetating,
 - d. Diverting rainwater away from areas in which it will become contaminated.

4.3.2 National level framework

These actions are well aligned with guidance at the national scale. The *Strategic Framework for managing abandoned mines in the Minerals Industry* (MCMPR/MCA, 2010) also provides a framework for state jurisdictions to adopt with a view to achieving convergence on:

- Site inventories and data management
- Improved understanding of liability and risk relating to abandoned mines
- Improvement performance reporting
- The standardisation of processes and methodologies
- Knowledge and skill sharing across jurisdictions.

4.3.3 Jurisdiction level risk management

From the perspective of leading practice abandoned mine management globally, key elements of a mature and resilient abandoned mine program have also been identified (see Unger et al, 2012), and provide support for the approach outlined in Box 1.

Figure 5 illustrates these elements and suggests actions under the key themes outlined in the *Strategic Framework for managing abandoned mines in the Minerals Industry* (MCMPR/MCA, 2010).

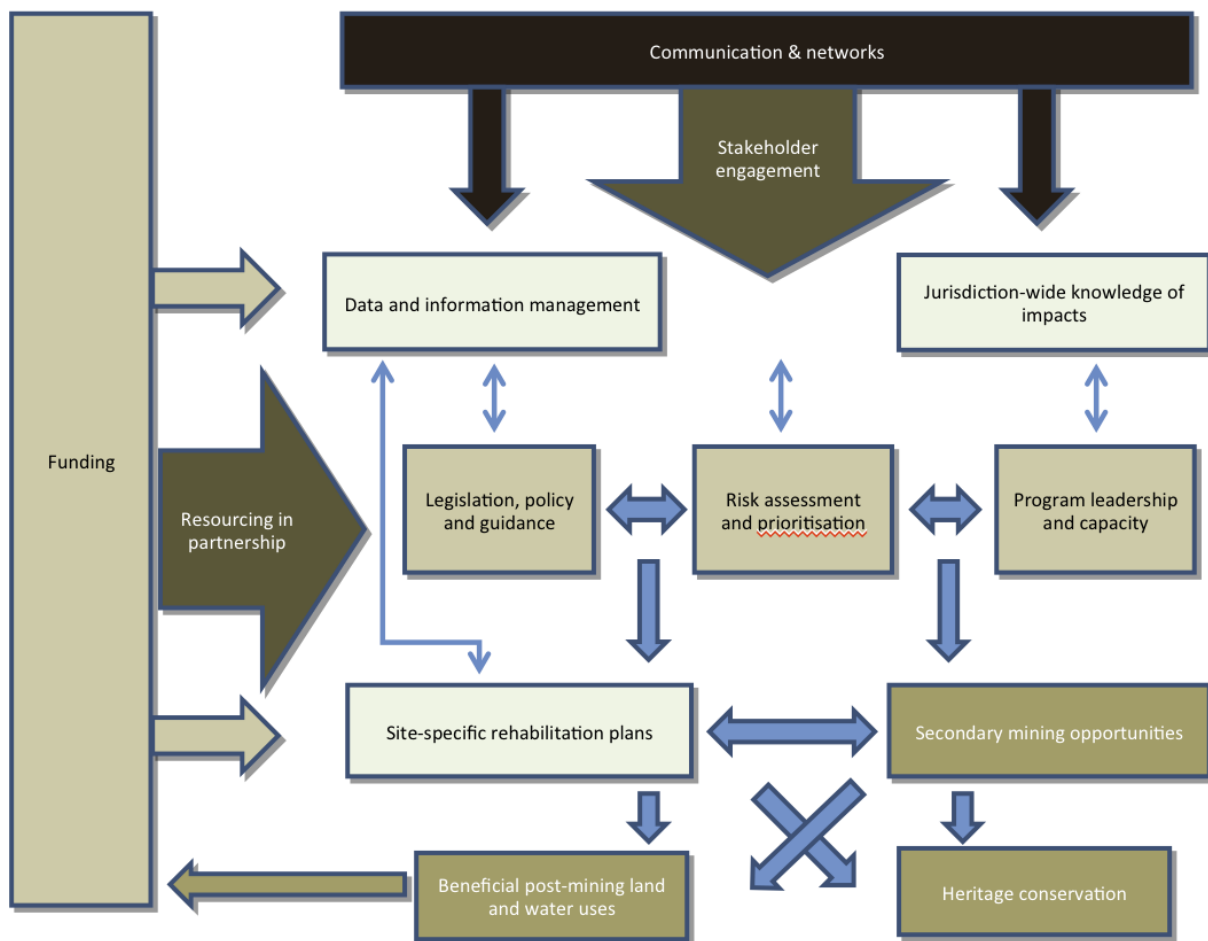


Figure 5: Conceptual model for an abandoned mine program (Unger et al. 2012)

Box 2: Case study – Mt Oxide abandoned mine, North Queensland

The Queensland Floods Commission of Inquiry (QFCI) (2012) used Mt Oxide and the 2010/2011 wet season as a case study to identify key recommendations to prevent impacts from abandoned mine flooding across Queensland in the future. It was identified that about 12,000 abandoned mines are located on private land and 3,000 on state owned land in QLD.

“The Abandoned mine land program has the primary purpose of ensuring human safety (Kadletz in QFCI, 2012) and secondary purpose to minimise environmental harm” (Brier in QFCI, 2012).



Figure 6: Contaminated creek near Mt Oxide

©Willis/Southern Gulf Catchment

The Mt Oxide mine is located on Chidna Station, north of Mt Isa in the Southern Gulf Catchments Natural Resource Management² area. Tributaries of Cave Creek drain runoff from the Mt Oxide site. Water flows to the Leichhardt River then to the Gulf of Carpentaria (Lawrence in QFCI, 2012). Mt Oxide was a copper mine operating from the 1920s until the last mining leases were surrendered in 1999 (QFCI, 2012). Cave Creek catchment is characterised by iridescent blue discolouration for more than 1 km downstream of the mine after rainfall (see Figure 6). The water flowing out of the mine is acidic – when it mixes with stormwater, dissolved metals precipitate onto creek beds (Kadletz in QFCI, 2012), and acid and metalliferous drainage comes from stockpiles of waste materials and leakage from the pit.

Water quality in Cave Creek sampled in March 2011 showed metals exceeded the acceptable levels set for the protection of ecosystems and human and livestock drinking water. Sediment samples also exceeded the sediment quality guidelines (Lawrence in QFCI, 2012).

The QFCI drew attention to the need for sufficient resources to investigate and monitor abandoned sites in order to develop sound management strategies to control AMD. The inquiry also drew attention to the lack of clarity over who was setting the environmental standards for control of AMD. The management of the site was the responsibility of the mines department so the environmental regulator, in the absence of an Environmental Authority and operating company, was not actively engaged in pre-wet season inspections or the setting of water quality standards from the site (R Lawrence in QFCI, 2012).

Three recommendations from the QFCI highlighted the need for high level oversight by both the environment (then Department of Environment and Resource Management) and mines (then Department of Employment, Economic Development and Innovation) departments and clarification of roles for management of new and existing abandoned mines (Recommendation 13.17³) as well as a comprehensive database of abandoned mine features and impacts on both private and public land (Recommendations 13.18 and 13.19⁴)

From an adaptation perspective the issues raised by the QFCI highlight the importance of the following at both national, state and site levels (for priority sites):

- Clearly defined departmental roles (legislation and policy) within government to ensure the same environmental standards which are set for active mining operations are applied to government departments managing abandoned mines to protect biodiversity, landowners and downstream land and water users;
- Good quality spatial data on residual mined land features for subsequent land managers and users and to quantify liabilities;
- Water monitoring and other investigations to inform risk assessment processes;
- Implementation of control measures following risk assessment to address significant safety, stability, pollution and sustainability risks; and
- Having undertaken remediation works monitoring must be undertaken to evaluate the effectiveness of these control measures and publicly report on performance.

² http://www.regionalnrm.qld.gov.au/my_region/index.html

³ 13.17 *The Queensland Government should determine which of its agencies should take responsibility for the management of all existing and new abandoned mine sites in Queensland (QFCI, 2012).*

⁴ 13.18 *The Department of Employment, Economic Development and Innovation should assemble all information currently available to the abandoned mine land program into a single database. The Queensland Government should ensure, using whatever information is available, that the list of abandoned mines is as complete as possible. This should at least include a review of all information held by the Department of Environment and Resource Management and the Department of Employment, Economic Development and Innovation. (QFCI, 2012).*

13.19 *The Queensland Government should seek information about the size, features and condition of abandoned mines, including whether the mine or its surrounding environment were adversely affected by flood, from private landholders who have abandoned mines on their properties (QFCI, 2012).*

As noted previously, in some instances legacy issues can be addressed by new mining projects at the site. However not all abandoned mines have potential for new mining, so prioritisation processes need to consider the realistic liabilities and assets of a site in the context of demand for specific commodity types in Australia. For those sites containing significant mining heritage values, such as those dotted along the mining heritage trail in South Australia⁵, key features need to be conserved (Burra Charter, 1999). This example and those in Cornwall England, e.g. have illustrated how adaptive re-use of these sites can assist with regeneration of communities as well as environments by providing beneficial post-mining land uses (Unger, 2010).

⁵ http://www.mininghistory.asn.au/wp-content/uploads/2012/10/sa_mining_heritage-90dpi.pdf

5 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 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.

5.1 Risks and Impacts

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; and
- 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.

5.2 Drought case studies

5.2.1 Drought Case study 2.1: Queensland Alumina Limited - Use of reclaimed town water

Location: Gladstone, Queensland

Operation type: Alumina Refinery

Mineral: Alumina

Operator: Rio Tinto Alcan 80% and Rusal 20%

QAL produces smelter grade alumina and occupies 80 hectares of a 3,050-hectare site including a wharf and storage facility on South Trees Island. Bauxite mined at Weipa in far north Queensland

is processed to produce Alumina through the four-stage “Bayer Process” involving grinding and ‘digestion’, settling of impurities, alumina crystal formation and calcination (high temperature drying of the crystals thus formed) (QAL, 2012).

In April 2002, drought conditions were declared, with the Gladstone Area Water Board reporting the region’s ‘worst recorded drought’ (see Corder and Moran 2006) conditions between 1996 and 2002. Water restrictions for industry, commercial and residential users were imposed in April 2002 (WSAA, 2009). Water restrictions reduced available supplies from an estimated 11GL per year of Awoonga Dam supply by 10%, and then by 25% seven months later (WSAA, 2009). These water restrictions, and their immediate impacts on operations, triggered the implementation of a two-year proposal for a collaborative project to treat and reuse municipal effluent in refinery processes.

Immediate impacts:

- Memorandum of Understanding signed with Gladstone council in July 2002 to implement existing proposal;
- Cost incurred for construction work for on the Calliope River Sewerage Treatment Plant, 8.5 km of pipeline through the city to QAL’s Parsons Point alumina refinery, and, receival works at the plant.
- Work completed in time to reduce impact of additional water restrictions in November 2002; and
- Project reduced the company’s water consumption by 2.5 GL/a (QAL, 2011).

Longer-term impacts:

- This is Queensland’s largest water recycling project; and
- In 2010, QAL and Gladstone Regional Council entered into talks to incorporate effluent from an additional source at the Boyne/Tannum sewerage plant into refinery operations (QAL, 2010) as a joint project with Gladstone Council 2010-2011 – it is estimated to reduce 1.1 GL of wastewater discharge per annum (Gladstone Regional Council, 2010b).

The bottom line

- The cost of the overall project of works in 2002 is not documented in publicly available materials, however actual costs are reported to have been \$0.9 million under total estimated cost. Gladstone Council is now contributing \$2.5 million for an effluent reuse scheme from Boyne/Tannum to QAL (Gladstone Regional Council 2010).

5.2.2 Drought case study 2.2: Cadia East – Cumulative impact and regulatory constraint

Location: 25 kilometres south-west of Orange, New South Wales

Mine type: Underground

Mineral: Gold and copper

Operator: Newcrest Mining

The Cadia East deposit is an expansion of operations on a site located near the Cadia Hill open pit and Ridgeway underground gold/copper mines. Cadia East is an underground deposit of porphyry related gold and copper that occurs 1,000 to 1,600 metres below the surface (Cadia East Holdings, 2008).

The expansion of mining activities in an area where two mines are already operating places additional pressure on water availability and adds to existing concerns about the impact on availability for other users (Hayes, 2010). For these reasons the conditions of consent for approval of the expansion have been extensive, with over a third relating to water use and issues of compensation (Hayes, 2010). The cumulative nature of the impact on water supplies on top those

used by existing operations, is particularly sensitive given the area is often under high levels of water restrictions.

Immediate impacts:

- To proceed, Cadia Valley Operations must invest substantial effort in carrying out a site water balance to detail the sources and security of its water supply, and conduct a series of studies on the pre-mining natural flows of surrounding waterways. The company will also be required to establish a program of monitoring for impacts on the groundwater supplies of local landowners.

Longer-term impacts:

- In the event that the mine adversely affects the water entitlement of a private landowner, the mine operators must also be prepared to provide compensatory supply within 24 hours of losses being detected (Hayes, 2010).

Adaptation actions and adaptation:

- While the investments in understanding the pre-mining water flows and existing water quality are intended to place Cadia Valley Operations in a position to reduce the risk associated with their use of local water, these investigations will also support additional adaptation actions in the future.

5.2.3 Drought Case study 2.3: Bulga – Thinking ahead about water security

Location: 15 km from Broke in New South Wales

Mine type: Open cut and underground

Mineral: Coking and Thermal Coal

Operator: Xstrata

The 5,500 hectare site known as the Bulga Complex, Xstrata produces approximately 16 million tonnes of semi soft coking coal and thermal coal per year. This material is transported by rail to the Port of Newcastle for export to China and Japan. The coal is used predominately for steel making and power generation.

Historically, the open cut Bulga mine has relied upon local surface water from the Hunter River to use washing and mining processes. Severe dry weather during 2007 prompted the identification of ‘water security’ as a risk to continuing operations (Laurence, 2011).

Immediate impacts:

- Investigations of opportunities to decrease reliance on the Hunter River;
- Increased use of stored water on site;
- New water management initiatives;
- Implementation of improved conservation procedures; and
- This includes the ‘use of underground raw water reuse, the secondary flocculation of tailing through the use of paste thickener’ (Xstrata, 2009) and installed filtration systems that enable use of bore water for dust suppression and washing (Xstrata, 2008).

Longer-term impacts:

- It is now company policy, as reported in the Xstrata Annual Report (2010) that all sites in water-scarce locations prepare and implement, in coordination with stakeholders, water management strategies, which include setting water intensity targets. Water availability is also clearly delineated as an area of operational risk for the company, and is incorporated into crisis and risk management planning processes (Xstrata, 2008);

- Water consumption from the Hunter River has been cut to 400 million litres from 1.6 billion litres (Xstrata, 2009); and
- Increases in recycled water usage have eliminated dependence on the Hunter River for water extraction.

Adaptation actions and options:

- Xstrata has committed to ongoing assessment of and action of potential climate change related risks and challenges to operations, inclusive of prolonged drought (Xstrata, 2009).

5.3 Summary of issues from case studies

As with flooding and storms, identifying hazards presented by drought conditions can be complex. Although drought conditions are less likely to appear with little or no warning, responses to prolonged drought can result in significant changes to the operating environment in a very short period of time. They can also entrench a ‘planning for drought’ mentality, which can underplay the future risk of floods and storms. Case studies included in this section illustrate both the speed at which change can occur, when water restrictions are imposed or increase, and the ways that mining and mineral processing operations have adapted to new circumstances. Success in reducing or eliminating such risks has required a clear understanding of operational water usage through audits and accounting procedures, identification of where water use, and water waste, can be minimised, and how substitutes may be leveraged through technology and innovation. Effective water valuation is a key element in supporting the identification of cost-effective measures that can be leveraged to improve water performance along the production cycle, and between uses in the community.

5.4 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, modify existing processes to address potential for equipment damage or failure, and lost production, case study mines, and the examples that follow, show how mining and mineral processing operations can avoid or limit the impacts by:

- Using water balance models to assist in making day-to-day decisions and to simulate supply, demand and storage requirements under various climatic scenarios (Laurence 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 & Schuchard, 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 (AGIC, 2011).

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 a plan for changes to supply, demand and storage requirements over the life of the mine (long-term) (Laurence, 2011).
- 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, 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, 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, 2009).

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

- Rio Tinto has utilised 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 (Laurence, 2011).
- Kinross has built redundant water storage facilities to contain process solutions and capture rainwater for use (Nelson and Schuchard, 2011)
- 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 in plant operations (Exxaro, n.d.)

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** include (Nelson & Schuchard 2011):

- 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 & Schuchard 2011).
- 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 more than 25 ML of potable water daily, providing 18 ML to nearby local municipalities while meeting all the company’s operational water needs (Anglo American, n.d.)

6 FEATURE: ADAPTING TO DROUGHTS AND FLOODS: MINIMISING ENVIRONMENTAL IMPACTS FROM MINE WATER MANAGEMENT SYSTEMS

Strategies for making efficient use of water at mine sites in dry periods (such as recycling and expanded water collection systems) can create problems when sites suddenly experience high rainfall events. For example, recent extreme rainfall events in Queensland have tested water management practices, infrastructure and regulation of mine water discharge.

6.1 Negotiating the complexities of alternating extreme weather events

In the past decade, mines in the Bowen Basin, Queensland have experienced extended periods of drought and water scarcity, followed by more recent periods of extreme flooding.

Where excess water from flood events overloads the water management system it may be impossible to continue with mining operations without releasing some or all of this excess. In the absence of an existing authorisation to release water, mining operations must seek regulatory approval to do so. Gaining this approval can be more complex and risky when applications are made a short notice, particularly if multiple mines in one catchment or region are making applications.

With increased recycling of saline water occurring during dry periods, additional water contamination risks can come from floodwaters mixing with stored sources of this poor quality water (see Box 3 for more detail). While such practices make sense when the climatic conditions are dry, stored water contamination limits a mining operation's ability to release water with no impact on the downstream environment and water users.

High dilution of release waters during flooding may reduce the risks posed by contaminants. However, the impacts and long-term consequences of this option may still be unacceptable to local communities and regulators. Such incidents can lower the confidence of local communities, both in the industry and the capability of governments to regulate to a particular standard, and this may lead to more stringent regulatory conditions and increased costs (see case studies 1.1, 1.2 and 1.3).

A useful strategy for creating confidence in a range of stakeholders, (including employees, affected communities and regulators) is to ensure that the impacts and consequences of such releases are understood prior to a flooding event. Pre-wet season planning and permitting will clarify these conditions where long-term trends and regional modelling indicate that an above-average wet season is likely (QFCI, 2012). Mine site contingency planning enables water balance modelling for a range of scenarios in order to predict potential outcomes. These can then be subjected to risk assessment methods to identify the significant risks and preventative control measures. These measures can then be applied to mitigate or eliminate regulatory, environmental and socio-economic risks.

Stakeholder engagement processes can also be used to reduce stress for communities, particularly if operational water management contingency plans have been prepared in advance, discussed and measures agreed upon.

6.2 Thinking about the catchment

Excess water, and decreased water quality, from multiple sites can lead to significant cumulative impacts for the catchment area or the region. For this reason, decisions made across different operations within a single catchment can also make a big difference to the options available for managing excess water. Understanding the likely cumulative impact within a catchment is therefore another useful strategy for developing an accurate sense of how an application to release waters may be handled by regulators under widespread flooding events.

Further risk management strategies might include exploring a regional or whole-of-catchment approach that is agreed upon in advance, between governments and industry, to mitigate problems before they arise.

Box 3: Bowen Basin Coal

Coal export losses following the 2010-11 floods have been estimated to be in the order of \$2 billion and 45 of the 57 coalmines in the Bowen Basin were affected by accumulation of water on sites (Vink and Robbins, 2012).

During periods of drought mines may redesign infrastructure to maximise the capture of as much rainfall/runoff as possible (QRC 2011 in Vink and Robbins, 2012) with an increased risk of accumulating too much water. This water may not meet water quality release criteria, when extreme rainfall events occur due to evapo-concentration and recycling of mine waters. Figure 7 below shows the increase in salinity of approximately 3,000–4,000 $\mu\text{S}/\text{cm}$ over only 6 months for one pit following flooding in 2007/2008 (Vink and Robbins 2012).

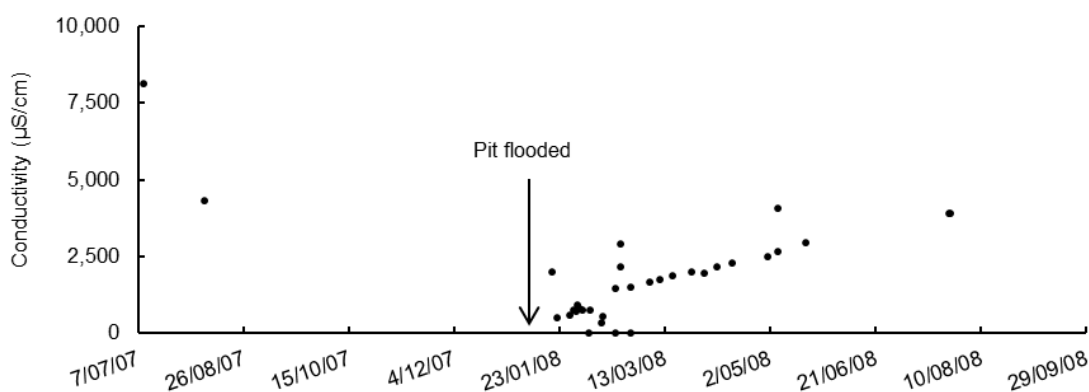


Figure 7: Electrical conductivity of water stored in a flooded mine pit in the Bowen Basin during the 2007-08 wet season (Vink and Robbins, 2012)

The cumulative pressure of increased saline water discharge to river systems in the region from the 2007/08 floods initiated a significant reform of mine water regulations. Studies (Hart 2009 in Vink and Robbins 2012; DERM 2009) found that mine discharge requirements were inconsistent across different operations, and that discharge water quality limits for some coalmines were insufficient to adequately protect downstream environmental values (DERM 2009). The end-of-pipe discharge (for EC) limits varied widely and in some cases, discharge timing was not linked to stream flow of the receiving waterways. While salts are essential to the physiology of all plants and animals, high concentrations of salts are toxic to freshwater plants and animals. Potential actions for mitigating these risks and impacts have been summarised further in this section.

6.3 Mitigating impacts through leading practice mine water management

Practices that can help to mitigate negative environmental impacts include:

- Clearly defined water quality objectives based on downstream environmental values – (use trigger values from toxicological testing) to manage controlled releases with minimal harm to aquatic ecosystems;
- Clear and consistent mine water discharge procedures to ensure releases are minimised and only occur when sufficient dilution occurs (using trigger values for contaminants known to present at sites in the catchment);

- Ensuring that mine water management infrastructure provides flexibility and contingency options for extreme weather conditions (both drought and flood);
- Improve water inventory systems for operational personnel to understand quality and quantity across all storages;
- Integrate real time hydrographic and water quality monitoring station data to support water management decision making (mine site, associated drainage network and government hydrographic station data);
- Incorporating synoptic seasonal climate outlooks into water planning;
- Undertaking progressive rehabilitation annually, to minimise soil and spoil erosion and to reduce rainfall runoff; and
- Designing tailings storage facilities to meet requirements of the life-of-operations – from commencement through to closure and post-closure.

6.4 Safety and environmental risks: tailings dams

There are at least two major storage failures annually worldwide, resulting in deaths and environmental disasters. Some of the potential impacts from such failures can be seen in the example provided by the collapse of a bauxite residue storage facility in Hungary. In October 2011 this resulted in eight deaths, a fine of €472 Million (\$US648 M), and the arrest of the Chief Executive Officer (Jones and Boger, 2012).

6.4.1 Reducing the impact and improving adaptive capacity by reducing tailings dams ‘footprint’

In Australia, Boger, (2009) has identified that an alumina plant can produce as much as 15,000 t/d (dry basis), while a copper mine could produce as much as 200,000 t/d (dry basis). Research has enabled the alumina industry to reduce the volume of waste produced by about 50 per cent worldwide, through the reduction of the tailings footprint (Jones and Boger, 2012). Although there remains a need to consider tailings geochemistry, and long-term weathering to avoid AMD generation in other commodity types, understanding and exploiting this new knowledge has resulted in dramatic improvement in the waste disposal strategy for some industries. In Australia, where water is increasingly at the centre of conflicts between mining and mineral processing operations and communities, reducing the use of water in managing tailings can improve performance under drought and flood conditions.

6.4.2 Reducing the suspension

Taking a ‘dry’ disposal approach to tailings management reduces the environmental impact of large tailings ponds (which require remediation later), by removing water from the suspension to produce a paste for stacking and drying. Removed water can be recycled and reused in operations and represents another step towards more sustainable practice in the industry. Under drought conditions this approach can improve water efficiency performance. When drought conditions are suddenly reversed, and large volumes of water are present across the site, a dry disposal approach to tailings can reduce the total volume of water on site and reduce its potential impact.

6.4.3 Taking a long-term view: designing tailings storage facilities for operations and beyond mine closure

The recently updated ANCOLD guidelines for tailings storage facilities (TSF) design emphasise ‘Integrated Life of Mine planning’. Europe provides examples of 800-year-old water storages that are being actively monitored, indicating that a design period of 1,000 years may be necessary. Planning for extreme periods of drought and flooding and longer-term climate cycles must be part of TSF design if both operational functions and post-closure stability are to be assured. Lack of control of the water balance, overtopping, and seepage due to poor design and /or construction are noted as key causes of failure in tailings dams.

Box 4: Key TSF planning objectives (ANCOLD, 2012)

1. *Optimal design for whole-of-life storage methodology (financially and environmentally)*
2. *Planning for the full cost of tailings disposal from conceptualisation to decommissioning and rehabilitation (socio-economic and environmental costs)*
3. *Full understanding of setting, risks and mitigation measures required*
4. *Financial modelling must take account of long-term risks (which discounted cash flow methods may underestimate) for potential consequences – cost, health, safety, environmental and community*
5. *Decisions should allow for adequate margins of safety, risks should be below levels that place undue exposure to hazards on third parties*
6. *Environmental impacts are minimised by initial design and also continuous program of management and monitoring*
7. *Robust closure planning of final landform, land use and environmental protection systems for post-closure environmental impact;*
8. *Management process that optimises and improves TSF operation so risks do not escalate during operations*
9. *Ensure adequate storage capacity and optimum performance for changes in storage volumes for early closure or extended long life*
10. *Full whole-of-life valuation of the TSF, and*
11. *Consider possible developments, beyond the immediate economic mine life, and build in flexibility where tailings are at risk of generating acid mine drainage (AMD).*

7 HIGHER TEMPERATURES, HEALTH AND SAFETY

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 impacts 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.

For example, 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. Mosquitoes can transfer viruses from themselves to a person (e.g. Barmah Forest virus), from one person to another (e.g. Malaria and Dengue fever), and can even be the mechanism that helps a virus move from one species to another (e.g. Ross River Fever; Murray Valley Encephalitis (MVE) Virus and Kunjin Virus (KV); bird-related viruses). Each of these viruses can result in a mild illness that could be mistaken for the flu or, in some cases, rubella (German measles). Some, such as MVE, KV, Dengue and Malaria can also result in serious illness or death.

Other examples include 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 for sites and surrounding communities.

An indication of how higher temperatures might affect risk at mining and mineral processing operations in Australia can be seen in the precautions and risk assessment actions of operations that are already very familiar with such conditions. Issues such as increasing heat-related illness and disease are areas in which international experience can provide guidance where tropical areas in the north of Australia do not already provide useful examples.

7.1 Risks and impacts

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

Direct impacts from higher temperatures include threats to the health and safety of site personnel (the exposure of workers to extreme heat can result in serious illnesses and injuries, and even death); as well as nearby communities. Other direct impacts arise from reduced productivity through:

- 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 lead to increased:

- Pressure on energy and water supplies and create conflict with other local users;

- Costs for maintaining a working environment that is well suited to workers and machinery; and
- Transmission of some diseases, putting site personnel at risk when they are on site but not actually ‘working’, and putting near-by communities at risk where disease ‘vectors’ can assist in the transmission of tropical diseases. The potential for this type of impact at a distance should not be underestimated in an industry where Fly-in -Fly-out workforce management practices mean that an infected person may be in the tropics one day at metropolitan Adelaide or Perth on the day following.

The case studies that follow are related to the potential impact of higher temperatures at mining and mineral processing facilities, and provide guidance for effective planning and management of these risks.

7.2 Higher temperature case studies

7.2.1 Higher temperature case study 3.1: higher temperatures and mosquito management

Location: MacArthur River, 50 km south west of Borroloola, Northern Territory

Mineral: Silver-lead-zinc

Operator: MIM Holdings (now Xstrata)

The MacArthur River mine demonstrates the complexity of managing mosquito populations in different locations. Situated 50 km south west of Borroloola, in the Northern Territory, the mine’s silver-lead-zinc operations are located in both coastal and inland areas. A 12 month study at 5 sites, including a site within the Borroloola township, revealed the presence of 27 species of mosquito, each with different breeding conditions, activity times and potential to carry disease (Montgomery, 1995). Two were known or suspected carriers of malaria, two were known carriers of Ross River Fever, one was a carrier for MVE and KE, while another species has been known to carry Ross River Fever, MVE, KE and Barmah Forest virus. Results from the study showed a number of different factors to be considered in assessing the potential risk, and options for eliminating, reducing or managing risk. However, prevention measures for almost all species are very similar.

These include:

- Monitoring permanent and temporary water sources on a regular basis to ensure that the presence of species that carry serious infectious illnesses is known and can be communicated to site personnel and any nearby communities (Montgomery, 1995, NSW Department of Health);
- Reducing access to permanent water sources including rainwater and septic tanks, tailings pond and impoundment areas, sediment ponds, decant ponds, silt traps, rain water run off areas (Montgomery, 1995); and
- Ensuring that site workers take precautions against being bitten (Montgomery, 1995).

Given the high mobility of mining workforces, it may also be useful to develop a screening process for workers coming from areas with high potential for carrying the viruses within two weeks of their arrival on site.

7.2.2 Heat stress

Despite improvements in working conditions across the industry generally, the Safety Institute of Australia has identified that workers in the mining industry remain particularly vulnerable to heat stress (Corleto, 2012). Ultimately, these symptoms directly impact, and increase, operating costs. The Safety Institute of Australia identifies that this complexity often requires specialist expertise and that generalist OHS professionals should have access to specialist occupational hygiene advice in high-risk situations, such as extreme temperatures (Corleto, 2012). However, the

remoteness of many mining and mineral processing operations may mean that immediate access to specialist expertise is limited.

Heat stress fatalities for underground workers have been much higher than they are at present (1:1000 ratio in 1930), with pre-selection screening, acclimatisation, education and other technological advances, the rate of death had fallen to 1:100,000 underground workers forty years later (Brake, 2011). In Australia, fatalities are very rare, though heat illness is common (Brake, 2011).

7.2.3 Higher temperature case study 3.2: Enterprise Mine – managing underground heat stress

Location: Mount Isa, Queensland

Mineral: Copper

Operator: Xtrata

The Enterprise Mine at Mount Isa, now owned by Xstrata, is expected to reach a final depth of 2,000 meters below the surface. At such depths, the impact of high surface ambient temperatures in summer combines with naturally occurring heat factors such as “autocompression” in the intake airways, virgin rock temperatures at 68 degrees Celsius, and increases of 10 degrees Celsius in temperature per 1,000 meters of depth to create conditions of heat stress in the work place that, without intervention, would exceed the levels that human physiology can withstand (Brake & Bates 1998; Mt Isa Mines, 2001). Techniques used at other Mount Isa mines include ‘flooding’ cooled air down the mine to reduce heat (Leveritt, 1998). However, the depth of the Enterprise Mine necessitates more targeted and continuous methods in addition to surface and underground bulk air-cooling and provision of chilled service water (Leveritt, 1998).

“Working in Heat” protocols have been put in place at the mines to ensure that the workforce has been acclimatized, and including triggers to ensure acclimatization by new personnel or those whose work has not previously involved work in high temperature conditions (Leveritt, 1998). Mandatory supervisory checks including dehydration tests and acclimatization cards, at least once a shift, have also been instituted (Leveritt, 1998). Additionally, the Enterprise Mine is the first Australian mine with a policy in place stipulating that all new mobile plants purchased for the mine should be air-conditioned (Mt Isa Mines, 2001). Finally, Mount Isa Limited has developed a highly efficient and low waste refrigeration solution (Mt Isa Mines, 2001).

7.2.4 Higher temperature case study 3.3: Surface heat related illness

In December 1997, a nineteen-year-old geology student, with little previous field experience died while sampling with a three-person team in Western Australia. After a single day’s work in weather conditions that were hot and dry (max 41°C, min 25°C, relative humidity 1 – 12 %), the student vomited several times over night, and continued to vomit the following morning. The investigation of the student’s death noted that by mid-morning he “was unable to continue work” and had “set off alone” to walk to the team’s vehicle to rest. Between his worksite and the vehicle he collapsed and was found dead some hours later (Torlach 1998).

This example illustrates the potential severity of heat-related illness for those working on the surface and highlights the need for all personnel, particularly those who are new to such conditions, to have high levels of awareness of symptoms, safety procedures and good communications. The investigator also advised that ‘no person’ should be working or travelling (especially alone) without adequate supply of drinking water, and that field workers should be encouraged to drink water regularly. In this case, the need for communication procedures and supervisory checks was also emphasised (Torlach 1998).

7.2.5 Higher temperature case study 3.4: Fimiston Open Pit (Superpit) Mine - Power Quality

Extreme heat can cause transmission lines to sag and short out. Additional heat generated by energy-draw on the transmission lines (i.e. when human communities are using air conditioning under high heat conditions) can exacerbate this effect. In these cases, the use of solar power (such as at Galaxy mines, WA) can assist, as hot and sunny days coincide with higher air-conditioning use. Where mining and processing operations use electricity infrastructure that is shared with other industrial and community users, there is a risk that responses to periods of extreme heat could reduce the power supply and power quality to all of these users. The Fimiston SAG mill alone uses 12 megawatts of power (enough to operate all the homes in 2 small towns) (KCMG 2012). Significant losses for mine operations, as well as large and small businesses using the same transmission lines, can occur when energy needed for critical equipment is either not available or of poor quality.

As noted in an earlier case study on the impact of flooding at the Kalgoorlie Super Pit mine, continuous pumping at the Super pit mine affects the quality of the power available to the mine and to the local community (Hodgkinson 2010).

7.2.6 Higher temperature case study 3.5: Karara Mine and heat related water conflicts

Location: 200km east of Geraldton, Western Australia

Mineral: Iron Ore (Hematite and Magnetite)

Operator: Gindalbie Metals (WA) and Anshan Iron & Steel Group (China)

Karara Mine, a \$1.8 billion project proposal, consists of hematite and magnetite processing operations including a magnetite concentrator.

Karara mine is only one of eight projects that have been approved for the region, and will require 5.3 GL (at full production of 12Mtpa) of the estimated 49 GL available in the Parmelia aquifer. Other mines have indicated that they will draw from the same source, resulting in opposition from established regional farming groups. Given long-term trends towards less reliable rain in Western Australian winters, and longer periods of drought, conflicts over access to water resources is likely to increase in the future, prompting some of the projects to explore alternatives.

Immediate impacts:

- 49 environmental conditions including a requirement for Karara to monitor water levels in the Parmelia aquifer at bores used by the facility and also at bores on neighbouring properties, as well as local wetlands (Gindalbie Metals Ltd 2012). Stage 1 production will utilise 3GL of the 5 authorised by the WA Department of Water to produce 8Mtpa of magnetite concentrate.

Longer term Impacts:

- Full production of 12Mtpa is estimated to require 5.3 GL, requiring the development of additional infrastructure to make up the shortfall.

Bottom Line:

- Licence issued following tests on water usage sustainability and aquifer testing costing a reported \$3 million dollars.

Adaptation actions and options:

- China's Citic Pacific has developed a 51 GL desalination plant for the organisations mining operations.
- Dry stacked tailings designed to reduce project water requirements by one third.
- Process water recycling

- Grey water recycling
Source: Gindalbie Metals Ltd (2012)

7.2.7 Higher temperature case study 3.6: Hazelwood mine bushfire **Location: Hazelwood, Victoria.**

Mine type: Open cut

Mineral: Thermal coal

Operator: International Power Hazelwood (now IPR-GDF SUEZ Hazelwood)

IPR-GDF SUEZ Hazelwood is located on 3,554 hectares in Victoria's Latrobe Valley and has a 1740MW power station and an adjacent brown-coal lignite mine. The Hazelwood mine supplies up to 18 million tonnes of brown coal per year to the power station (IPR-GDF SUEZ n.d). The presence of coal dust at the mine and in the surrounding area, have resulted in numerous fires, and the adaptation of vehicles and nearby homes to reduce the potential for impact.

During the 2006 Victorian bushfires, the entire western face of the Hazelwood mine caught fire, burning for two weeks in walls of coal up to 30 meters high, for two kilometres along the coalface (Leigh, 2010). Extinguishing the fire required 200 CFA fire-fighters, mine staff, and two water bombing aircraft (The Age, 2006). Damage from this fire has been estimated at \$300 million and involved teams from across the state in a 24-hour-a-day operation.

Immediate impacts:

- Production was halted, leading to a cut of approximately one third in Hazelwood Power Station electricity production;
- Damage to equipment including one coal dredger and a conveyer belt that feeds coal into the power station;
- Evacuation of employees; and
- Threat to nearby community residents – residents on nearby roads were placed on high alert.

Longer-term impacts:

The Hazelwood operation became the subject of a merger with IPR-GDF SUEZ in 2011.

Lower rainfall and very high evaporation rates have led the business to pump water from the nearby Hazelwood Cooling Pond to the mine as part of its fire prevention and dust suppression strategy.

Adaptation actions and options:

IPR-GDF SUEZ Hazelwood is responding to changing climate patterns through its environment, safety and emergency planning processes. Major assets, such as dredgers and conveyors are protected through a complex fire suppression system of mains, headers, rotary sprays and hydrants. A Safety Management Audit Committee and an Environmental Management Committee meet every two to three months to review IPR-GDF SUEZ Hazelwood's safety and environmental performance (International Power Hazelwood, 2005)

7.2.8 Summary of issues from case studies

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. Examples used in these case studies demonstrate that being aware of 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 both 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.

7.3 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. Case studies included in this section outline several risks of extended periods of higher than average temperatures.

Examples of how international mining operations are adapting to some of these risks include:

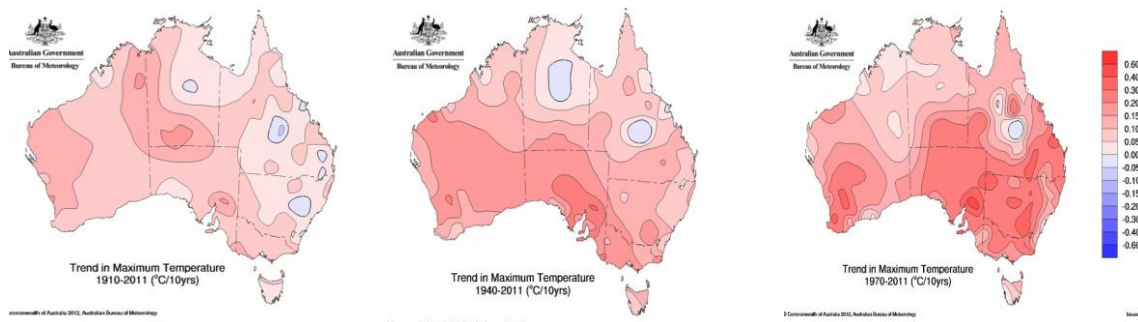
- Modifying existing risk-identification processes to incorporate additional heat-related health risks, e.g.:
 - Harmony Gold Mining introduced an awareness campaign to promote early diagnosis of malaria (Nelson and Schuchard, 2011); and
 - Cameco introduced pandemic preparedness procedures as part of its emergency planning; they also engaged with Saskatchewan Fire Services to conduct an independent audit of its mitigation controls and response measures for forest fires (Nelson and Schuchard, 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;
 - Food handling related operational health and safety.

7.4 Looking forward: long-term trends for temperature

The maps in Figure 8 (below) show the long-term trends of past temperatures across Australia.

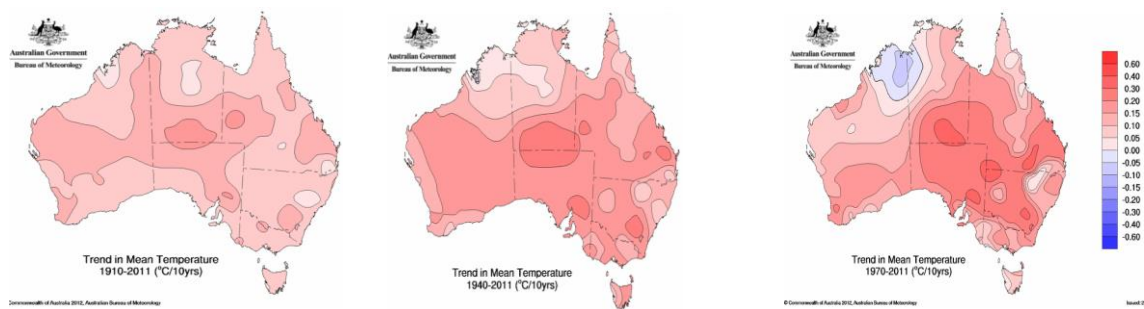


Source: Maps of Average Climate, Bureau of Meteorology, Australia. © Bureau of Meteorology

Figure 8: Time series of annual maximum temperatures (national) 1910 – 2011 (left); 1940-2011 (centre) and 1970-2011 (right) (BOM 2012)

Annual maximum temperatures across most of Australia have been rising since 1910. Particularly in inland regions on southern Australia; the warming trend has intensified since 1970.

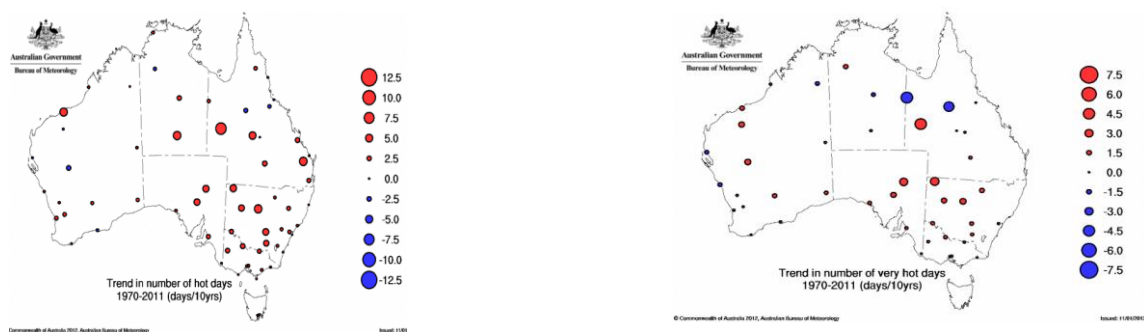
Figure 9 (below) shows annual mean temperatures have also been rising across almost all of Australia since 1910, and especially in the 40 years to 2011. The trend in mean temperatures is indicative of ongoing changes to Australia's climate.



Source: Maps of Average Climate, Bureau of Meteorology, Australia. © Bureau of Meteorology

Figure 9: Time series of annual mean temperatures (national) 1910–2011 (left); 1940–2011 (centre); 1970–2011 (right) (BOM, 2012)

Another useful indicator of climate is that for the number of 'hot days' from 1970 to 2011, which is shown below in Figure 10.



Source: Maps of Average Climate, Bureau of Meteorology, Australia. © Bureau of Meteorology

Figure 10: Time series of 'hot days' and 'very hot days' 1970 – 2011 (BOM 2012)

The first map shows the trend in the number of days above 40 degrees (known as a 'very hot day') and the second shows the trend in the number of days above 35 degrees (known as a 'hot day'). In addition to rising mean and maximum temperatures, there is likely to be an increase in the number of hot days and very hot days. Increases in number of hot and very hot days are likely to increase the risks associated with heat stress, energy demand and may also increase risks from food-borne disease.

7.5 Impacts from changes to temperature

These observations are broadly aligned with IPCC projections based on global data. CSIRO reports that the best estimate of annual warming over Australia by 2030 is around 1.0°C, with warmings of around 0.7-0.9°C in coastal areas and 1-1.2°C inland (CSIRO, 2007).

Implications: Areas experiencing higher temperatures could also experience changes to water usage for mining and mineral processing, particularly if these operations are located near communities. Changes to land use patterns for agriculture might also change the potential distribution of local water sources.

Risks identified: Higher temperatures will require a greater focus on cooling equipment and keeping personnel safe and comfortable in warmer conditions, both day-to-day and through the

seasons. Other risks range from disease-related to increased mosquito activity, food spoilage and water quality (Australian Productivity Commission 2011). Risks and impacts from increased or changed mosquito activity have been outlined in case study 3.1. Further guidance on reducing such risks has been provided in this report.

Food spoilage risks may arise from a number of common, food-borne, illnesses that are influenced by the temperature of processing and preparation environments. The United States Department of Agriculture Food Safety and Inspection Service identify temperatures between 32 and 43 degrees Celsius as optimal for bacterial growth, particularly in areas of high humidity where the moist environment allows bacteria to flourish (United States Department of Agriculture Food Safety and Inspection Service 2011). Longer periods of higher temperatures will require greater attention to conditions for food processing (off site) and preparation (onsite). For instance, Salmonella, which can cause diarrhoea, nausea, vomiting, abdominal pain, fever, headache, is more likely to occur when there are higher ambient temperatures during processing. For this reason, direct risks of food poisoning at a mine site may increase as a result of higher than average temperatures in areas, hundreds or thousands of kilometres away. Other sources of food poisoning may increase due to conditions for onsite food preparation, where an increase the incidence of gastroenteritis may occur.

8 UNCERTAINTY, RISK ASSESSMENT AND ADAPTIVE PLANNING

8.1 Uncertainty, risk, and decision-making

While it is not possible to accurately predict what will happen in the future, it is possible to take actions that are likely to help prepare and plan for the challenges presented by a range of future situations. This approach is a key element of standard workplace health and safety risk analysis and management, as outlined below:

- Hazard identification
- Risk assessment
- Implementation of controls
- Effective monitoring
- Comprehensive review.

Using this system mining and mineral processing operations have been successful in identifying a range of hazards, developing measures to address these hazards, and then actively monitoring the impact of the measures. Review periods provide an opportunity to evaluate the accuracy of the risk assessment, and the effectiveness of the measures. They also provide an opportunity to look at new information and adjust systems and measures, where necessary.

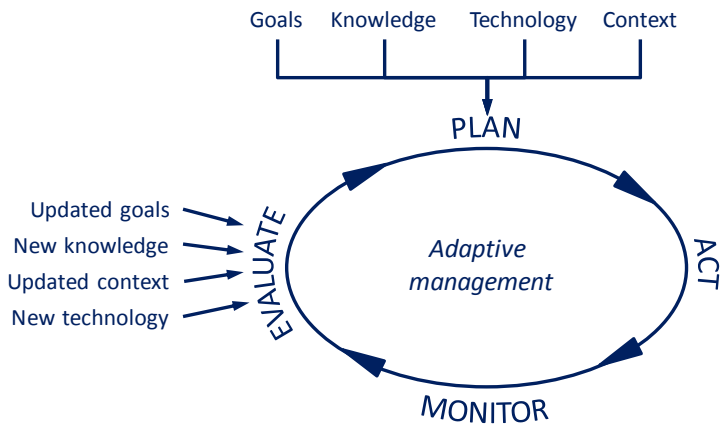
8.2 Adaptive planning – learning by doing

Adaptive planning is an approach to making decisions in an environment of high uncertainty (Grant 2003, Stankey et al 2005). Adaptive planning has been applied in business management, different industry contexts as well as in a range of natural resource sectors. At its simplest, it is the process of ‘learning by doing’, and then creating new value by incorporating this new knowledge into future practices and development. Although there may be large elements of uncertainty involved in a decision, it is possible to develop an adaptive planning approach that allows you to begin working an objective based on the things that are known (e.g. legal requirements, details of the physical layout of the site, costs for lost production time) while information is collected on unknown or uncertain aspects, such as annual or seasonal weather patterns and historical flood levels. As more information becomes available, the existing plan can be regularly reviewed and revised based on a better understanding of what is involved.

In business management terms adaptive planning has been identified in approaches such as total quality management, continuous improvement, and learning organisations (Senge 1990 in Stankey et al 2005). In a natural resource context, such as forestry, agriculture, water resource management and fisheries, adaptive management is described as a way to link “...learning with policy and implementation” by modifying subsequent behaviour in light of that experience...” (Stankey et al 2005).

8.2.1 Northwest Forest Plan

The United States Department of Agriculture’s Northwest Forest Plan is an example of ‘learning by doing’, and was implemented between 1994 and 2004. Figure 11 shows the process that was used to achieve the goal of initiating an “ecosystem-based management approach” to 9.7 million hectares of federal land across three-state regions. Ten areas across forest reserve were designated as sites where testing of different management practices could be undertaken, and where the standards and guidelines proposed for use in the broader reserve could also be tested and validated. A further aspect of the experimentation looked at the impact of relations between land managers and citizens.



Source: adapted from Stankey et al 2005 – Figure 2 The adaptive management cycle (USDA USDI 1994)

Figure 11: Example of a natural resource oriented adaptive management cycle

8.2.2 Vision, alertness and responsiveness: improving coordination in a new context

Examples of adaptive planning in the oil industry have been outlined in a study of ten leading oil and gas oil majors which outlined the development and implementation of a more broadly distributed approach to strategic planning as a response to a ‘radical transformation of their industry environment’ during the 1970s. This shift is seen as response to the need to improve “...coordination between business units” by using ‘broadly defined goals’ for key business objectives (i.e. net income targets, cost reductions) for which these business units were given responsibility. Key tools for adaptive planning in this context were mission and vision statements that communicated and guided strategies of different business units, the replacement of single-point forecasts with alternative scenarios of the future that would assist with contingency planning and encourage a state of “alertness and responsiveness ... to changing market circumstances.”. Another adaptive approach was seen in the shift from “forecasts of key variables” such as prices and currency exchange rates, to the use of “assumptions about these variables” in the form of ‘reference prices’ which were then used as a basis for financial projections and performance targets that served as a consistent foundation against which financial performance could be targeted and monitored (Grant 2003). Figure 12 (below) outlines the generic approach described in this oil case study:



Source: adapted from Grant 2003, Figure 2. The generic strategic planning cycle among the oil majors

Figure 12: Example of a mining and mineral processing oriented adaptive management cycle

A key characteristic of adaptive planning is the circular nature of the process, which allows for a strategy, set of goals or objectives to be developed and for the outcomes of initiatives aimed at achieving these goals to be monitored, evaluated for effectiveness. Finally, this information is examined with a view to incorporating the lessons learned and acknowledging outcomes in the next cycle of planning. Further details about developing an adaptive plan of management, and a brief description of several tools utilised in adaptive planning are provided on the following pages. For minerals industry professionals, familiarity with such processes and documentation of outcomes is important, as corporate knowledge is easily lost when staff turnover.

8.2.3 Adaptive planning using an 'iterative' approach

Figure 13 shows a generalised approach to a planning cycle that goes through five phases, on an ongoing basis, to ensure that changes to underlying assumptions or objectives are always being taken into account. When first undertaken, the initial phase involves an assessment of objectives, risks and vulnerabilities, the next two phases involve the identification of indicators (for success or failure) and data sources that can tell you about your present performance. The fourth phase involves collecting the data and analysing it. The fifth phase is used to check that your objectives are being met, and if not, what might need to be adjusted.

A second cycle will begin with incorporating new information, and any changes to objectives, risks and vulnerabilities, into existing planning, by making adjustments suggested by the final phase of the previous cycle.



Figure 13: Adaptive planning cycle (adapted from Crawford 1999)

The following table outlines these phases and the sources of information/guidance that different approaches can offer to the process of adaptive planning. More details on the approaches shown in this table are provided on subsequent pages.

Table 1: Phases of adaptive planning and sources of information

Phase	Sources of information and guidance
<p>1. Identifying and/or revising objectives, risks and vulnerabilities</p>	<p>‘What if’ analyses and risk assessments can be used to identify risks that should be addressed in a course of action. All of the above processes can also be informed by expert judgments and advice.</p> <p>Consultation with a wide range of stakeholders (employees, local communities, regulators, shareholders) can also be useful in identifying risks and objectives.</p> <p>Scenarios can be a good way to explore the robustness of objectives under different circumstances.</p>
<p>2. Identifying or revising indicators for success and failure to meet objectives</p>	<p>Expert judgments and advice can also be used to help determine good indicators for success or failure. Consultation with people and personnel who are most familiar with areas where success or failure will emerge, or long-term experience at a particular site, can help ensure that indicators are relevant, can also provide valuable source of useful information about early indicators of trouble</p>
<p>3. Identifying or revising data that will inform your indicators</p>	<p>Expert judgments and advice can assist with the collection and storage of data, analysis and modelling of local climate conditions. Consultation with people and personnel, who are most familiar with or have long-term experience at a particular site, can help ensure that data is practical to collect and relevant to the indicators.</p>
<p>4. Collecting and analyse data</p>	
<p>5. Evaluating factors contributing to success or failure and revise objectives, indicators, data as needed</p>	<p>If your analysis indicates that you are not making progress towards your objectives for success, or showing signs of failing, you can call on expert judgement, and consultation with site personnel and other relevant informants, to work out where adjustments need to be made. This may include changes to policies, practices, strategies, indicators or sources of data. It may even include changes to objectives if these are not the most useful way of making a successful adaptation.</p>

The following sections explore topics of risk assessment, future thinking and scenarios, and consultation, showing how they could be applied across the five phases of the adaptive management cycle. The colours used in Figure 13 and Table 1 appear at the top of each topic section to indicate which of the phases are most relevant to the information provided.

8.2.4 Risk Assessment

There are several approaches to risk assessment. Risk assessment usually relates to a particular exposure unit, which may be individual, population, infrastructure, building or environmental asset. The process usually involves **identifying hazards that could have an impact**, assessing the **likelihood and severity of potential impacts**, and assessing **the significance of the risk**.⁶ Approaches, methods and tools that can help with assessing risks are provided below.

Can be applied to phases:		1	2	3	4	5
Approach	Examples and associated methods/tools					
Vulnerability assessment is an assessment of the vulnerability of a community's human, natural and physical infrastructure to climate variability and severe weather. Such an understanding provides a basis for setting adaptation policy priorities by identifying areas that require new policies or partnerships, and areas of emerging opportunities.	Consultation, Scenario development based on expert judgement of future conditions, future vulnerabilities are estimated based on these scenarios, and potential adaptation strategies are identified, options and their potential to reduce vulnerability evaluated,					
What-if analyses take a variety of forms, but each begins with posing "What if?" questions in a structured brainstorming session. This is commonly used in risk management to anticipate potential problems and suggest response strategies and ways of mitigating the risk. Example questions include, "What if available water supplies dropped by 20% during the summer? What changes in water policy would be required for various uses, given this condition?" Such analyses are common with HAZOPs (Hazard and Operability Studies)	This technique can be used to initiate discussion about what impacts may occur under certain changes in climate, and generate ideas of appropriate responses. This technique could be used in a focus group or workshop setting that gathers together experts on the general subject area (e.g. agricultural or engineering experts) or the specific area of application (e.g. planners and engineers at the city).					
The case study is an approach to investigating complex social phenomena within a real-life context, and can be used to explore, describe or explain an observed situation.	The use of case studies is commonly to answer "how" or "why" questions about contemporary events where an understanding of how the context relates to observed outcomes is desired (Yin 2004).					
Expert judgments are evaluations performed by people who have a particular expertise relating to the question at hand. The judgments can be of at least two types, and are commonly a bit of both: that is, they may be issues of factual judgment (something that can be proven right or wrong) or of value judgment (expressing an opinion) that derives from expert knowledge of the issue being evaluated.	The World Bank advocates this approach for identifying the region, sub-region, district, water basin, and time horizon (i.e. 2020, 2050, 2100), of a climate risk analysis. Expert judgement is also advocated for use in assessing trends and long-term projections of annual and seasonal precipitation, water runoff, temperature and other key factors (World Bank, Guidance Note 3).					
Sources: Bizikova L., T. Neale and I. Burton 2008. Appendix 1: (pp. 63-69); World Bank 2008						

8.2.5 Examples of different climate risk assessment approaches

Three examples of risk assessments developed for changes to climate are provided here. The first is a climate risk assessment developed by the World Bank. The second combines risk assessment with an evaluation of the opportunities for creating value by making changes. A third example is taken from an approach to assessing potential impacts of mining on local groundwater.

⁶ UKCIP in DEFRA UK (2010)

Risk Assessment Example 1: World Bank Climate Risk Assessment

The table below is an example of how this international organisation is advising development professionals on dealing with climate risk for natural resource projects such as agriculture and mining. In this example, the risk assessment lays out questions that should be answered (first column) and approaches or tools that can be used to answer these questions.

Table 2: Steps and approaches (World Bank, 2008)

Main question / step	Approaches/tools
What is the study area (region, sub-region, district, water basin, etc.), and the time horizon of interest (i.e. 2020, 2050, 2100)?	Expert opinion, project team's interests.
What is the nature and extent of current and future climate risks in the area of interest? What is the degree of uncertainty?	Application of user-friendly tools such as the World Bank Climate Portal, literature review, climate trend analysis, application of Global Climate Models (GCMs) and Regional Climate Models (RCMs)
What are the most important climate variables to which agriculture and NRM sectors may be sensitive to in the study area (i.e. trends and long-term projections of annual and seasonal precipitation, water runoff, temperature, number of consecutive dry days, etc.)?	Literature review and expert opinion. See also use of Seasonal Climate forecasts and Early Warning Systems.
What coping strategies are being used to deal with current climate variability? Are adjustments necessary in face of longer-term changes?	Review of existing information on current local risks, vulnerability and coping strategies.
What is the extent and nature of the sector's sensitivity and vulnerability to changes in climate variables in the study area over the assessment period (i.e. impacts of increasing droughts, soil erosion, or increased precipitation on crop yields production)?	Employment of user-friendly sector- and location-specific climate risk screening tools... use of agronomic models, surface water runoff models, etc. coupled with climate projection models.
What are the non-climate-related drivers of risk and vulnerability in the study area (i.e. land-use change, soil degradation, lack of basic rural infrastructure, lack of income diversification opportunities, distortion in agricultural subsidies, etc.)? What are the uncertainties involved? What is the importance of climate vulnerabilities vs. the other vulnerabilities (i.e. market volatility, infrastructure, health)?	Field surveys, participatory rural appraisals interviews with key informants and local communities.... Special attention should be given to how these impacts affect the most vulnerable and disadvantaged populations, including women, children and marginalized groups
Given all the above, what are suitable adaptation options in the study area?	Suggested adaptation measures from climate risk screening tools (see below), outcomes of the field surveys, results from adaptation projects / studies in other areas, interviews with key informants and local communities, expert opinion.
Given all the available options, which ones should be carried out first?	Participatory approaches ... economic analysis.

A range of country-based and climate changed themed resources are available from the World Bank's online research library. Guidance notes on adaptation to climate change in agriculture and natural resource management projects can be found at:
<http://climatechange.worldbank.org/content/adaptation-climate-change-agriculture-and-natural-resource-management>

Risk Assessment Example 2: Evaluating Risks and Opportunities

The second example of a climate-related risk assessment has been adapted from and developed in Canada for use by local government and community. This assessment differs from the first example in that it also addresses the potential for opportunities to arise from actions taken to adapt to new circumstances. This example uses five categories with different criteria to identify and prioritise potential adaptation options. Each category can be used separately or used to identify adaptation options that are 'high priority' across multiple categories.

Table 3 (below) deals with criteria for the category of "risk and uncertainty". Using the criteria of "urgency" combined with "degree of risk" and "understanding of risk" a range potential adaptation options can be assessed as being of high, medium or low priority. Under this system of assessment an adaptation option or action would be considered of high priority if:

- Impacts were already occurring
- Risks were potentially catastrophic or irreversible
- And the nature of the risk was not well understood

Table 3: Evaluating the risks and opportunities (adapted from *Canadian Guidebook for Adaptation to Climate Change – Step 4 p.45*)

Category	Criteria	High Priority	Medium Priority	Low Priority
Risk and uncertainty	Urgency	Impacts are already occurring	Impacts are beginning to occur, or likely to occur in the near to mid-term	Impacts or risks for impact are likely to occur in the long-term
	Degree of risk or impact	Future risks are potentially catastrophic or irreversible	Future risks are moderate and reversible	Future risks are minor and reversible
	Understanding of risk	The risk is not well understood	Some uncertainty exists	The risk is well understood

In a similar manner, table 4 (below) deals with criteria for the category of "opportunity". Using the criteria of "ancillary benefits" combined with "no regret piggy backing" and "window of opportunity" a range potential adaptation options can be assessed as being of high, medium or low priority. Under this system of assessment an adaptation option or action would be considered of high priority if it:

- Contributes significantly to other goals of the company or operation;
- Results in significant benefits regardless of actual climate change impacts (i.e. whether or not a risk becomes an impact); and
- Aligns with a window of opportunity.

Table 4: Evaluating the opportunity factors (adapted from *Canadian Guidebook for Adaptation to Climate Change – Step 4 p.45*)

Opportunity	Ancillary benefits	Measure will contribute significantly to other goals of the company or operation	Measure will contribute somewhat to the other goals of the company or operation	Measure will contribute little or nothing to the other goals of the company or operation
	No-regret option Piggy backing	Measure will result in significant benefits regardless of actual climate change impacts	Measure will result in some benefit regardless of actual climate change impacts	Measure will result in little or no benefit if climate change impacts do not occur
	Window of opportunity	A window of opportunity exists	A window of opportunity could be created	There is currently no window of opportunity

Table 5 (below) deals with criteria for the category of “effectiveness”. Using the criteria of “robustness” combined with “reliability”, a range potential adaptation options can be assessed as being of high, medium or low priority. Under this system of assessment an adaptation option or action would be considered of high priority if it:

- Is effective in a wide range of possible future scenarios; and
- Is a proven method for achieving the specified goal

Table 5: Evaluating the effectiveness factors (adapted from *Canadian Guidebook for Adaptation to Climate Change – Step 4 p.45*)

Effectiveness	Robustness	Effective across a wide range of plausible future scenarios	Effective across many plausible future scenarios	Effective for a narrow range of plausible future scenarios
	Reliability	The effectiveness of the measure is proven	Experimental but has expert support	This measure is untested

Table 6 (below) deals with criteria for the category of “implementation”. Using the criteria of “public acceptability” combined with the availability of “funding sources”, “capacity” and “institutional factors” that provide a range potential adaptation options can be assessed as being of high, medium or low priority. Under this system of assessment an adaptation option or action would be considered of high priority if it:

- Is likely to receive public support;
- Funding is available (internal or external funds);
- Skills, time, and other internal resources are sufficient to the measures identified; and
- Can be undertaken without the need for external approval

Table 6: Evaluating the implementation factors (adapted from *Canadian Guidebook for Adaptation to Climate Change – Step 4 p.45*)

Implementation	Public acceptability	Likely to receive public support	Not likely to receive much public attention or support	Likely to face public opposition
	Funding sources	Funding is available	External funding sources are required and likely to be secured	External funding sources are required but have not been identified
	Capacity	Current capacity is sufficient	Gaps exist in one or more areas but can be addressed	Current capacity is insufficient and gaps cannot be easily addressed
	Institutional factors	Implementation is within local control	Implementation requires external approval	Implementation requires coordination with, or action by other jurisdictions

Table 7 (below) deals with criteria for the category of “Sustainability”. Using the criteria of “mitigation co-benefits” combined with the availability of “environmental impacts”, “equity”, “implementation cost” and “operation and maintenance cost” that provide a range potential adaptation options can be assessed as being of high, medium or low priority. Under this system of assessment an adaptation option or action would be considered of high priority if it:

- Would reduce greenhouse gas emissions;
- Results in net environmental benefits;
- Results in benefits to many people;
- Costs of implementation are low compared to the costs of doing nothing; and
- Costs of operating and maintenance are low.

Table 7: Evaluating the sustainability factors (adapted from *Canadian Guidebook for Adaptation to Climate Change – Step 4 p.45*)

Sustainability: Social, Economic, Environmental	Mitigation co-benefits	Would reduce greenhouse gas emissions	Would not affect greenhouse gas emissions	Would increase greenhouse gas emissions
	Environmental Impacts	Result in net environmental benefits	Result in no-net loss of habitat or ecosystem services	Result in environmental costs
	Equity	Significant benefits to many people	Benefits to many people	Benefits to few people
	Implementation cost	Cost of implementation is low relative to cost of inaction	Cost of implementation is moderate relative to cost of inaction	Cost of implementation is high relative to cost of inaction
	Operating and maintenance cost	Cost of operation and maintenance is low	Cost of operation and maintenance is moderate	Cost of operation and maintenance is high

Risk Assessment Example 3: Evaluating Risks

The following example is taken from Framework for Assessing Potential Local and Cumulative Effects of Mining on Groundwater Resources (SKM, 2010)

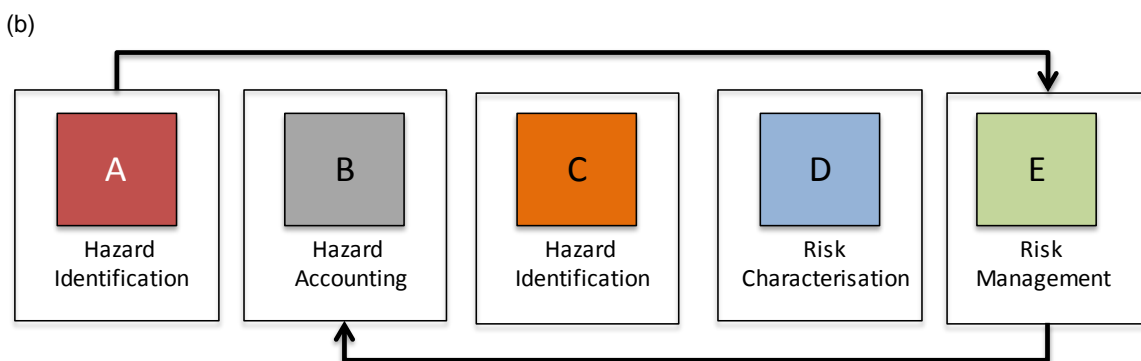


Figure 14: Overview of risk assessment approach (a) Guiding principles to a risk assessment (from enHealth, 2002) and (b) Recommended steps within a risk assessment framework (from Smith et al. 1998)

The above schema provides an overview, which could be used to adapt to risks from drought, heat, extreme weather and a changing climate. Characterising the consequence and likelihood is an important part of planning an appropriate management strategy.

8.2.6 Implementing adaptive planning: thinking about the future and scenarios

While it is not possible to accurately predict what will happen in the future, it is possible to take actions that are likely to help prepare and plan for the challenges presented by a range of future situations. Approaches, methods and tools that may be useful in thinking about the future are outlined below:

Can be applied phases:		1	2	3	4	5
Approach	Examples and associated methods/tools					
Scenario development and analyses are methods for exploring possible changes in the future. Scenario analysis is a systematic evaluation using expert judgment and scientific methods to identify a range of possible outcomes that could occur, taking into account key drivers and the uncertainty surrounding them. This is the method used in the IPCC reports to develop future climate scenarios. (See page x)	<p>Synthetic scenarios, also known as “arbitrary” or “incremental” scenarios, are the simplest climate change scenarios to construct and apply. This is done by using historical climate records and altering a climate variable by an arbitrary amount to see how it affects the system. (also referred to as a Sensitivity analysis)</p> <p>Analogue scenarios use existing climate information, either from the site being studied (“temporal” analogue) or from another location whose current climate is similar to that expected for the study site in the future (“spatial” analogue).</p>					
Storylines and Alternate Futures describe plausible social, economic, technological and political changes that will have a bearing on future conditions and adaptation possibilities.	For the United Kingdom Climate Impacts Programme, four socioeconomic scenarios were developed alongside climate scenarios in order to produce an integrated climate impact assessment. Socioeconomic scenario development is also useful for promoting social learning about climate change impacts in the community (Berkhout et al., 2002 in Bizikov et al 2008).					
Sources: Bizikova L., T. Neale and I. Burton 2008. Appendix 1: (pp. 63-69); World Bank						

Example: Scenarios and Shell

As noted on the global website for the Shell company, scenarios have been used by Shell to assist them in forming a “deeper understanding” of global developments, energy supply, use and needs, as well assist in making “crucial choices in uncertain times” (Shell 2011). They used scenarios in place of forecasts to assess readiness for a distinct range of futures.

“Shell has placed particular weight upon strategic planning as a vehicle for organizational learning. Shell’s scenario planning process was primarily a process for sharing and integrating multiple knowledge bases from both within and outside the Shell group. Shell’s ‘scenario-to- strategy’ framework involved discussion workshops in which scenarios would provide the foundation for an interactive strategy formulation. To maximize the organizational learning occurring through the strategic planning process, Shell has attempted to make explicit the perceptions and judgments of the various decision makers within the strategy process through techniques such as ‘mental mapping.’ “ (Grant 2003)

Shell is still using scenarios both in their own planning and in the services that they offer to partners.

8.2.7 Getting input and Consultation

Consulting with different people may be one of the best ways to find out what is happening on the ground, or during specific process and activities, and what might be possible in terms of a response to extreme weather events.

Can be applied phases:		1	2	3	4	5
Approach	Examples and associated methods/tools					
<p>Facilitated workshops are method that aims to bring out the ideas, concerns and preferences of participants in a structured decision-making process. It contributes to a learning process individually and collectively that simultaneously incorporates diverse beliefs and values to develop joint recommendations on preferred actions.</p>	Useful in to apply information to develop ideas and provide judgments on options. One of several “participatory approaches” advocated by the World Bank Guidance Note 3 () for use in climate risk assessment processes.					
<p>Focus groups bring together around six to ten selected participants representing groups or individuals whose ideas and opinions are of particular interest for the discussion topic.</p>	A focus group is guided by a facilitator, through an interactive discussion around specific questions in order to learn from participants’ experience.					
<p>Brainstorming focuses on generating many ideas without evaluating the merits of those ideas—critical judgment of ideas is reserved for a subsequent step in the process.</p>	Unusual ideas are welcome, and there is an emphasis on building on and extending proposed ideas to come up with ever more creative possibilities (e.g. see What-if analyses)”					
<p>Expert judgments are evaluations performed by people who have a particular expertise relating to the question at hand. The judgments can be of at least two types, and are commonly a bit of both: that is, they may be issues of factual judgment (something that can be proven right or wrong) or of value judgment (expressing an opinion) that derives from expert knowledge of the issue being evaluated.</p>	The World Bank advocates this approach for identifying the region, sub-region, district, water basin, and time horizon (i.e. 2020, 2050, 2100), of a climate risk analysis. Expert judgement is also advocated for use in assessing trends and long-term projections of annual and seasonal precipitation, water runoff, temperature and other key factors (Guidance Note 3).					
Sources: Bizikova L., T. Neale and I. Burton 2008. Appendix 1: (pp. 63-69); World Bank 2008						

9 ADDITIONAL RESOURCES

This section outlines additional resources relevant to topics covered in the case studies.

9.1 Adaptation Guidance

9.1.1 Climate Change

Assessing climate change risks and opportunities for investors: Mining and Minerals Processing Sector

ANU and Investor Group on Climate Change (2013)

This guide provides information to help investors assess and integrate climate risk and opportunity in the mining and minerals processing sector into investment analysis.

http://www.igcc.org.au/Resources/Documents/mining_assessing%20climate_change_risks_for_investors.pdf

Adaptation to Climate Change in Agriculture and Natural Resource Management

World Bank (2008)

A series of eight guidance notes covering engagement of institutions and communities, assessing risk, strengthening capacity, and monitoring and evaluation of measures.

<http://climatechange.worldbank.org/content/adaptation-climate-change-agriculture-and-natural-resource-management>

Assessing Climate Change Risks and Opportunities for Investors

Mining and Minerals Processing Sector (2013)

This guide provides information to help investors assess and integrate climate risk and opportunity in the mining and minerals processing sector into investment analysis.

http://igcc.org.au%2FResources%2FDocuments%2Fmining_assessing%2520climate_change_risks_for_investors.pdf&ei=_AxRUeGpF8ntiAfQnYH4Bw&usg=AFQjCNFSnUDVuQ1O_Irajm4Ef8EWnRB6uw&bvm=bv.44158598,d.aGc&cad=rja

Climate adaptation in the Australian mining and exploration industries

CSIRO (2010)

This 42-page report details the process and findings of a workshop conducted in Kalgoorlie-Boulder, Western Australia in August 2010 investigating mining industry adaptation to climate change in the Goldfields region.

http://www.csiro.au/~media/CSIROau/Flagships/Climate%20Adaptation/GoldfieldsVulnerabilityWorkshop_CAF_PDF%20Standard.pdf

Extreme Weather Events and the Mining Industry

SKM Consulting (2011)

This resource provides guidance on assessing climate risk and incorporating climate knowledge into mine management.

<http://www.skmconsulting.com/Knowledge-and-Insights/Achieve-Articles/2011/ExtremeWeatherEvents.aspx>

Guideline for Climate Change Adaptation

Australian Green Infrastructure Council (2011)

Developed to assist industry address climate change risks and opportunities for new infrastructure projects or existing assets and developing appropriate adaptation measures.

http://www.agic.net.au/agic_cca_guideline_v2.1_final_22_12.pdf

IPCC Fourth Assessment Report

Intergovernmental Panel on Climate Change (2007)

Three working group papers and a synthesis report that brings the key elements of each working group paper together. Working group papers are based around the 'physical science', impacts, adaptation and vulnerability, and mitigation of climate change.

<http://www.ipcc.ch/ipccreports/ar4-wg1.htm>

9.1.2 Floods and Storms

Assessing Risk

Australian Government, Emergency Management Australia

In an article titled *Flood Risk Management in Australia*, the National Flood Risk Advisory Group discusses and presents the National Flood Risk Management Guideline.

Source: Australian Government Emergency Management Australia. (2008). Assessing Risk. *The Australian Journal of Emergency Management*, 23(4).

Floodplain Management in Australia: Best Practice Principles and Guidelines

CSIRO (2000)

The book provides a set of best practice principles and guidelines for the management of flooding associated risks across the Australian floodplains.

<http://www.publish.csiro.au/Books/download.cfm?ID=2260>

Mitigating the Adverse Impacts of Flood, bushfire and Landslide

Queensland Government Department of Local Government and Planning (2003)

This State Planning Policy ('the SPP') sets out the State's interest in ensuring that the natural hazards of flood, bushfire, and landslide are adequately considered when making decisions about development.

<http://www.dsdiq.qld.gov.au/resources/policy/spp-ifbl.pdf>

National Guidelines for the National Flood Risk Information Program

Australian Government – Australian Emergency Management

At this preliminary stage, the document represents a grouping of principles and practices concerning Australian current knowledge and understanding of how best to develop and use flood risk information nationally.

<http://www.em.gov.au/Publications/Program%20publications/Pages/National-Guidelines-for-the-National-Flood-Risk-Information-Program.aspx>

Natural Hazards in Australia: Identifying Risk Analysis Requirements – Chapter Five: Flood

Geoscience Australia

Identifying the impacts, risks and role of management for floods.

Source: Middlemann, M. H. (Ed.). (2007). Flood. *Natural Hazards in Australia: Identifying Risk Analysis Requirements* (pp. 59–80). Canberra: Geoscience Australia. Retrieved from

https://www.ga.gov.au/image_cache/GA10873.pdf

Planning for Stronger, More Resilient Floodplains

Queensland Government, Queensland Reconstruction Authority (September 2012)

Planning for stronger, more resilient floodplains is a two-part Guideline that provides Councils with a suite of practical measures to better align floodplain management and land use planning.

<http://www.qldreconstruction.org.au/publications-guides/land-use-planning/planning-for-stronger-more-resilient-flood-plains>

Risks of Sea Level Rise for Australia

Department of Climate Change

<http://www.climatechange.gov.au/~media/publications/coastline/cc-risks-full-report.pdf>

Tailings Management – Leading Practice Sustainable Development Program Handbook

Department of Resources, Energy and Tourism

This handbook discusses a systematic, risk-based approach to tailings management. It provides examples of tailings containment, disposal and rehabilitation, and points to future trends in tailings management.

<http://www.ret.gov.au/resources/Documents/LPSDP/LPSDP-TailingsHandbook.pdf>

Understanding Floods: Questions and Answers

Queensland Government (2011)

The document draws on a national and international technical expertise to provide a scientific and engineering perspectives around definition, forecasting, warning, and planning around floods. The document also investigates opportunities and gaps in best practice flood management for Queensland.

Water Management – Leading Practice Sustainable Development Program Handbook

Department of Resources, Energy and Tourism

Water is integral to mining activities and typically the prime medium that can carry pollutant into the wider environment. The aim of the handbook is to provide a guide to operational managers on a structured approach to water management. It does not attempt to address detailed technical water management at a site operator level.

<http://www.ret.gov.au/resources/Documents/LPSDP/LPSDP-WaterHandbook.pdf>

9.1.3 Drought and Higher Temperatures (including bushfires)

Bushfire Smoke Online Factsheet

NSW Department of Health

This fact sheet provides useful information on what you can do to avoid or reduce the impact of bushfire smoke on employee and community health.

<http://www.health.nsw.gov.au/factsheets/environmental/bushfire.html>

Assessing risks of hot environments

The Safety Institute of Australia Body of Knowledge framework

Heat stress is a prominent WH&S concern; it impacts directly on the individual and is an indirect contributor to many incidents in Australian workplaces. Chapter 26 of the Knowledge framework presents a systematic three-tiered approach to risk assessment in hot environments. This chapter details how to conduct a level 1 assessment of heat related risks (which can be carried out by people with little or no technical or specialist skill) and level 2 and 3 assessments (which require specialist skills).

<http://www.ohsbok.org.au>

Bushfire CRC Publications

Bushfire CRC

This resource provides guidance on fire and risk management, hazardous materials, health and safety, fuel management, fire weather, community safety, communicating risk, and basic wildfire awareness. <http://www.bushfirecrc.com/>

Guidance on Equipment and Machinery Use in Bush Fire Prone Areas, prepared by the NSW Rural Fire Service

http://www.rfs.nsw.gov.au/file_system/attachments/State08/Attachment_20050228_BC9B4268.pdf

Guidance on reducing and managing coal dust

United States Department of Labor

This resource identifies basic steps to take to reduce and manage coal dust. It notes that the National Fire Protection Association has not assigned a flammability rating to coal dust however identifies that other sources rate coal dust as a fire hazard and consider the airborne dust an explosion hazard when these substances are exposed to heat or open flame.

<http://www.osha.gov/SLTC/healthguidelines/coaldust-less5percentsio2/recognition.html>

Guidelines for Preventing Mosquito Breeding Sites Associated with Mining Sites'

Department of Health and Families, Northern Territory

Outlining requirements to incorporate mosquito management in mine operations' Environmental Management Plans.

<http://www.health.nt.gov.au/library/scripts/objectifyMedia.aspx?file=pdf/32/40.pdf&siteID>

Heat Stress: Management and Prevention of Heat Stress Guideline

Mines Occupational Safety and Health Advisory Board (MOSHAB) DIR, Western Australia

Discusses the regulatory framework for working in hot environments in Western Australia and gives examples of working situations where heat may be involved. Covers heat stress factors, effects of thermal stress on the body, methods of reducing heat stress (load), and evaluation of heat stress (load). Ways of minimising the potential for heat strain are also discussed.

<http://www.dmp.wa.gov.au/documents/Guidelines/>

Infectious Diseases Online Factsheets

NSW Department of Health

Brief overview of symptoms, effects, prevention measures and information about reporting cases.

<http://www.health.nsw.gov.au/factsheets/infectious/index.asp>

Managing Electrical Risks in the Workplace Code of Practice

Safe Work Australia

<http://www.safeworkaustralia.gov.au/sites/SWA/AboutSafeWorkAustralia/WhatWeDo/Publications/Pages/Managing-Electrical-Risks-in-the-Workplace.aspx>

MHSA Safety Manual 6 – Heat Stress

United States Department of Labor - Mining Health and Safety Administration

Covers heat stress and strain and heat control mechanisms in the human body. This manual also describes signs heat-related disorders and appropriate treatment. Heat stress control measures are also described.

<http://arlib2.msha.gov/awweb/main.jsp?flag=browse&smd=1&awdid=2>

Mine sites, exploration camps and construction villages: Public Health Considerations

Government of Western Australia, Department of Health

This scoping tool identifies a range of public health factors that need to be considered in the early planning stages for mining activities, exploration camps and accommodation villages.

<http://www.public.health.wa.gov.au/cproot/3937/2/Mine%20sites%20and%20exploration%20camps%20JUNE%202011.pdf>

OSHA Factsheet: Working Outdoors in Warm Climates

United States Department of Labor - Occupational Safety and Health Administration

Hot summer months pose special hazards for outdoor workers who must protect themselves against heat, sun exposure, and other hazards. Employers and employees should know the potential hazards in their workplaces and how to manage them.

http://www.osha.gov/OshDoc/data_Hurricane_Facts/working_outdoors.pdf

OSHA Technical Manual Section III: Chapter 4 - Heat Stress

United States Department of Labor - Occupational Safety and Health Administration

Provides descriptions of heat disorders, investigative guidelines, sampling methods, control, PPE.

http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html

Planning for Bushfire Protection – a guide for councils, planners, fire authorities, developers and home owners

NSW Rural Fire Service

www.bushfire.new.gov.au

Mine Dust Online Factsheet

NSW Department of Health

This fact sheet helps you to understand and explain the type of dust that is generated from mine sites and the potential risks from mine dust to health. Mine dust can reach neighbouring properties and in the event of a bushfire can significantly increase risk to human health and amplify damage caused. http://www.health.nsw.gov.au/factsheets/environmental/mine_dust.html

9.2 Data Sources

Australian fire weather (as represented by the McArthur Forest Fire Danger Index and the Canadian Forest Fire Weather Index)

Centre for Australian Weather and Climate Research, Technical Report No. 10

http://www.bushfirecrc.com/managed/resource/ctr_010.pdf

Climate Data Online

Bureau of Meteorology

Climate Data Online provides access to a range of statistics, historical weather observations, climatology maps, and other Australian climate data.

<http://www.bom.gov.au/climate/data/>

Australian Flood Studies Database Search

Geoscience Australia

A list of all flood occurrences, related studies and findings across Australia.

Available at: http://www.ga.gov.au/flood-study-search/search.do?townName=&catchmentRiver=&stateTerritory=ALS&fromYear=1980&fromMonth=1&toYear=2012&toMonth=10&northLat=&westLon=&southLat=&eastLon=&action_search=Search

Australian Online Coastal Information

GeoScience Australia

Australia's online coastal information: provides comprehensive information about Australia's coast, including its estuaries and coastal waterways.

http://www.ozcoasts.org.au/climate/sd_visual.jsp

9.3 Further case studies

Australia's Dynamic Water Industry: Fostering Excellence in Water Management

Case studies in water management innovative best practice across Australia's economy, including the minerals and resources sector.

www.austrade.gov.au/.../1358/Water-Innovation-Booklet.pdf.aspx

Coalfires worldwide

This website provides links to research and case studies of coal mine fires. These provide insights into the range of impacts of coal fires and how to monitor and manage coal fire risk.

http://www.coalfire.org/index.php?option=com_content&view=category&id=15:research-results&Itemid=27&layout=default

Occasional Paper No.23 - Case studies in commercial and industrial water savings

WSAA

<http://www.waterforlife.nsw.gov.au/waterefficiency/businesses>

Strategic Water Management in the Minerals Industry – A Framework

Minerals Council of Australia and the Ministerial Council on Mineral and Petroleum Resources

The framework sets out the strategic issues – including Valuing Water; Strategic Water Planning; Implementation; and Engaging Stakeholders - that minerals operations should consider for responsible water management at a site and corporate level to reduce risks. Case studies of best practice are provided in the guide.

http://www.ret.gov.au/resources/Documents/mcmpr/Strategic_Framework_for_Water_Management_in_the_Minerals_Industry.pdf

Water for the Minerals and Energy Sector

CSIRO

The Minerals Flagship Research centre is supporting the minerals and energy sectors to use water efficiently while improving environmental outcomes.

<http://www.csiro.au/Outcomes/Water/Water-for-the-resources-sector.aspx>

Mining adaptation case study report: Learning from the Fortescue Metals Group (FMG) Extreme Weather Events Risk Assessment project

CSIRO

This report briefly describes and distils lessons from the Extreme Weather Events Risk Assessment project commissioned in 2011 by the Fortescue Metals Group (FMG) for their expanding Pilbara iron ore and infrastructure developments.

http://www.csiro.au/~media/CSIROau/Flagships/Climate%20Adaptation/CAF_MiningReports/FMG_CCAreport.pdf

9.4 Tools and modelling

Fire Regimes and Sustainable Landscape Risk Management Project

Bushfire CRC This project focused involved the FIRESCAPE landscape/fire regime simulation model. The modelling aims to measure the responses of biodiversity to different fire regimes and the sensitivity of fire behaviour to vegetation, fuel moisture, landscape characteristics and fire suppression and prevention activities. The modelling enables quantification of risks posed by particular fire regimes.

<http://www.bushfirecrc.com/projects/b12/fire-regimes-and-sustainable-landscape-risk-management>

Guidance on the application of workplace exposure standards for airborne contaminants

Safety Australia

This Guide provides advice on the application of workplace exposure standards for airborne contaminants (exposure standards) in the workplace. This Guide should be read in conjunction with the Workplace Exposure Standards for Airborne Contaminants. In some jurisdictions specific guidance is also provided by regulators, e.g. the Simtars Model in the Queensland Mining Industry* and the WA Mining Industry Model**.

<http://www.safeworkaustralia.gov.au/sites/SWA/AboutSafeWorkAustralia/WhatWeDo/Publications/Pages/interpretation-airborne-contaminants-guide.aspx>

OzClim

OzClim provides a simple step-by-step option to help you generate and explore climate scenarios. There are also six scenarios in the examples section for rainfall and temperature for 2030. The advanced section is designed for the scientific research community and policy making. Choose from twenty-three climate models, eight emission scenarios and three climate sensitivities.

<http://www.csiro.au/ozclim/home.do>

Water Accounting Framework for the Minerals Industry.

Mineral Council of Australia

MCA has developed an Input Output Model to support existing company water reporting requirements. Implementation Manual and Input-Output Model Framework template, are available from the MCA website to assist minerals industry users in applying the framework.

http://www.minerals.org.au/focus/sustainable_development/water_accounting

*SIMTARS - Queensland Mines and Energy, *Adjustment of occupational exposure limits for unusual work schedules*, http://mines.industry.qld.gov.au/assets/inspectorate/exp_standards_adj.pdf.

**Western Australian Department of Minerals and Energy, (1999), *Adjustment of Exposure Standards for the Extended Workshifts: Guideline*, Perth.

9.5 Training

Climate Change Adaptation Planning

Australian Water Association

This course was developed in response to a call from AWA members. The course will assist attendees to better understand the adaptation risks their organisation face due to climate change; help them to take the first steps in developing a climate change adaptation plan; and will identify tools that will support them in implementing their plan.

http://www.awa.asn.au/Climate_Change_Adaptation_Planning.aspx

10 PREPARING FOR THE FUTURE

The synthesis represented in this guide has raised awareness of adaptation issues and options for mining and minerals professionals. It found that:

- Climate events can impact heavily on mining operations and communities;
- There is a business case for improving planning and preparation to incorporate adaptation;
- Case studies exist that provide examples of the impact of events and leading practice examples that can be used to improve responses;
- Information exists to support greater understanding of historic and future climate trends; and
- Existing or modified planning processes can be used to support risk assessment and adaptive planning:
 - Managing changes to the risk profile of mining and mineral processing operations is something that is already embedded in existing management processes.

In this sense, climate change adaptation is just one more tool that can be used by professionals to reduce or eliminate risk. Both risk management and adaptive planning have been successfully applied to confront uncertainty in a range of countries and industries.

While uncertainties will remain, several areas for adaptation to climate impacts have the potential to successfully address both the business objectives of mining and mineral processing operations and the broader social and environmental concerns of key stakeholders. The areas for adaptation are:

- Increased awareness of risk and need for preparedness;
- Increased ability to manage water scarcity and abundance on the same site;
- Increased resilience in energy supply and efficiency of use which may involve changes to the energy mix;
- Adapting to impacts of heat stress on site and for fly-in-fly-out workforce; and
- Contributions to carbon sequestration capacity.

This project has made a significant contribution to understanding these issues better, and can be built on over time to support an increasing knowledge base for practitioners.

Importantly, for mining and minerals professionals to lead the adaptation response at both sites and in corporate headquarters of companies – open and collaborative knowledge sharing is essential. This knowledge exchange must connect between disciplines within the professions as well as between company stakeholders and shareholders. Embracing an adaptive management learning cycle to confront a changing climate can strengthen the learning and ultimately, the preparedness of companies and the communities in which they operate.

Box 5: Bowen Basin - Learning the lessons from recent extreme weather events

Australia is not only a location of extreme natural climate variability but is one of the world's most vulnerable regions to climate change. In 2012, a study aimed at identifying the impacts and effects of extreme weather events in the Bowen Basin coal-mining region of Queensland, including the responses to these events by the mining industry, dependent communities and related stakeholders, including government.

Some of the key lessons for the mining industry included:

- *The role of short-term thinking, either because of short time horizon planning agendas or high staff turnover.*
- *Companies can be vulnerable to abrupt switch from current conditions to a new set of risks (e.g. from drought to floods or vice versa).*
- *The need to obtain and use both seasonal and short-term climate forecast knowledge provided by the Bureau of Meteorology (BOM) in planning ahead of the wet season;*
- *The need for mine flood-water discharge criteria that protects the environment and are reasonable, effective and consistent;*
- *The need for site-specific requirements concerning water quality and quantity in future adaptation planning.*

The project was led by the Centre for Social Responsibility in Mining at the University of Queensland in collaboration with the CSIRO and funded by the National Climate Change Adaptation Research Facility (NCCARF). The full report can be found at <http://www.nccarf.edu.au/>

Acknowledgement of source: CSIRO

Box 6: Foundations for understanding projections of future climate change impacts

There are three main foundations that have been used to understand the potential impacts and implications of climate change in Australia. Extrapolation based on long-term trends of observed climatic conditions by the Australian Bureau of Meteorology, National Tidal Centre, and Geoscience Australia, have been highlighted in previous sections. In addition to long-term trends, models can be used to evaluate the risk and impact potential that different circumstances present. Those most relevant to the Australian context are the IPCC global models, and regional models for Australia developed by the CSIRO (2007). Table 8 (below) provides a high level summary of each IPCC model. Each is based on a 'storyline' and 'scenario family' that can be applied to different situations.

Table 8: Overview of IPCC scenarios

Model name and "Storyline" description:	"Scenario families" (underlying assumptions of storyline)
<p>A1 - "...a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies."</p>	<p>In this scenario:</p> <ul style="list-style-type: none"> • There is NO CLIMATE POLICY • the world is MARKET ORIENTED • the economy is FASTEST GROWING (per capita) • the population PEAKS BY 2050 • governance is based on STRONG REGIONAL INTERACTIONS and INCOME CONVERGENCE • technology underlying economic growth is understood under THREE DIFFERENT OPTIONS <ul style="list-style-type: none"> ○ A1FI – Fossil fuel intensive ○ A1T – non-fossil energy sources ○ A1B – 'balanced across all sources'

A2 – “... a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities.”

In this scenario:

- There is NO CLIMATE POLICY
- the world is DIFFERENTIATED
- the economy is REGIONALLY ORIENTED with LOWEST GROWTH (per capita)
- the population is CONTINUOUSLY INCREASING
- governance is based on SELF RELIANCE with PRESERVATION OF LOCAL IDENTITIES
- technology experiences SLOWEST and MOST FRAGMENTED development

B1 – “...a convergent world with ... global population that peaks in mid-century and declines thereafter... but with rapid changes in economic structures toward a service and information economy...”

In this scenario:

- There is NO CLIMATE POLICY
- the world is CONVERGENT
- the economy is SERVICE and INFORMATION BASED with LOWER GROWTH THAN A1
- the population PEAKS BY 2050
- governance is based on GLOBAL SOLUTIONS to ECONOMIC, SOCIAL and ENVIRONMENTAL SUSTAINABILITY
- technology is CLEAN and RESOURCE EFFICIENT

B2 – “...a world in which the emphasis is on local solutions to economic, social, and environmental sustainability.”

In this scenario:

- There is NO CLIMATE POLICY
- the world looks for LOCAL SOLUTIONS
- the economy experiences INTERMEDIATE GROWTH
- the population is CONTINUOUSLY INCREASING (more slowly than A2)
- governance is based on LOCAL SOLUTIONS to ECONOMIC, SOCIAL and ENVIRONMENTAL SUSTAINABILITY
- technology develops MORE RAPIDLY THAN A2, and LESS RAPIDLY THAN A1/B2 with GREATER DIVERSITY.

(Source: IPCC 2000, pp. 3, 4-5 and Carter et al 2007, p147)

As shown in Table 8 (above), there are no assumptions about the existence of policy changes for climate change in any of the scenarios. There is also a range of options for important factors, such as the fuels that might be used by industry. For example, the A1 model has three separate approaches to the energy mix that supports projected changes to population and economic growth.

Regional scenarios developed by the Commonwealth Science and Industry Research Organisation CSIRO in the report Climate Change in Australia (2007) utilised the IPCC scenarios, and local data from different regions of Australia, to try and understand what future circumstances might bring.

The key messages from this study were that:

- Australia’s “Intense rainfall events in most locations will become more extreme, driven by a warmer, wetter atmosphere.
- The combination of drying and increased evaporation means soil moisture is likely to decline over much of southern Australia.
- An increase in fire-weather risk is likely

Figure 15 provides an easy reference guide to the type of changes that the CSIRO regional model has suggested will occur under different emission scenarios.

Figure 15: Geographical climate impacts: Australian summary
 Source: Adapted from CSIRO Chapter 3 Future Australian climate scenarios 2007 (updated 2011)

Top End

Remote area communities to face increased exposure to heat stress, fire, diseases, extreme rainfall events, and flooding. 80% loss of biodiversity in Kakadu wetlands for a 30 cm sea-level rise.

Darwin

Present averages: Temp: 27.8C; Days over 35C: 11; Rainfall: 1847 mm pa	Projected 2070 Averages (low-emissions): Temp: 29.5C; Days over 35C: 89; Rainfall: 1829 mm pa
Projected 2030 Averages (mid-emissions): Temp: 28.8C; Days over 35C: 44; Rainfall: 1847 mm pa	Projected 2070 Averages (high-emissions): Temp: 31C; Days over 35C: 227; Rainfall: 1829 mm pa



South-west Western Australia

Decline in annual stream flow. Wheat yield significantly reduced by 2070.

Perth

Present averages:
Temp: 18.5 C; Days over 35C: 28; Rainfall: 747 mm pa

Projected 2030 Averages (mid-emissions):
Temp: 19.3 C; Days over 35C: 35; Rainfall: 702 mm pa

Projected 2070 Averages (low-emissions):
Temp: 19.9 C; Days over 35C: 41; Rainfall: 665 mm pa

Projected 2070 Averages (high-emissions):
Temp: 21.2C; Days over 35C: 54; Rainfall: 605 mm pa

Southern South Australia

Sea-level rise may increase the cost of sand replenishment on Adelaide beaches. Farming of land at the drier fringe likely to be increasingly marginal if rainfall declines substantially. Grape quality in the Barossa Valley likely to decline due to higher temperatures.

Adelaide

Present averages: Temp: 16.5 C; Days over 35C: 17; Rainfall: 463 mm pa	Projected 2070 Averages (low-emissions): Temp: 18 C; Days over 35C: 26; Rainfall: 430 mm pa
Projected 2030 Averages (mid-emissions): Temp: 17.4 C; Days over 35C: 23; Rainfall: 444 mm pa	Projected 2070 Averages (high-emissions): Temp: 19.3 C; Days over 35C: 36; Rainfall: 403 mm pa

Northern Coastal Queensland

Sea-level rise likely to cause salt-water intrusion and inundation in some Torres Strait Islands. Significant loss of biodiversity in the Great Barrier Reef and Queensland Wet Tropics by 2020. Risk of inundation by a 1-in-100-year storm surge in Cairns area may more than double by 2050.

South East Queensland

Less water for cities, industries, agriculture, and natural ecosystems. Less frost damage to crops, higher wheat yields but lower wheat quality, increased pest and disease risk. 20% increase in intensity of a 1-in-100-year rainstorm could, for example, inundate 7,000 properties in the Nerang catchment in southern Queensland.

Brisbane

Present averages: Temp: 20.5 C; Days over 35C: 1; Rainfall: 1192 mm pa	Projected 2070 Averages (low-emissions): Temp: 22.1 C; Days over 35C: 3; Rainfall: 1133 mm pa
Projected 2030 Averages (mid-emissions): Temp: 21.5 C; Days over 35C: 2; Rainfall: 1109 mm pa	Projected 2070 Averages (high-emissions): Temp: 23.6 C; Days over 35C: 7.6; Rainfall: 1085 mm pa

New South Wales and ACT

Average stream flow decreases across the Murray–Darling Basin by 2030. 10–40% increase in the number of extreme fire danger days in Canberra by 2020. Annual heat-related deaths in Sydney rise from 176 (1990s) to 364–417 by 2020.

Sydney

Present averages: Temp: 18.3 C; Days over 35C: 3.5; Rainfall: 1277 mm pa	Projected 2070 Averages (low-emissions): Temp: 19.9 C; Days over 35C: 4.4; Rainfall: 1225 mm pa
Projected 2030 Averages (mid-emissions): Temp: 19.2 C; Days over 35C: 4.4; Rainfall: 1238 mm pa	Projected 2070 Averages (high-emissions): Temp: 21.3 C; Days over 35C: 8.2; Rainfall: 1174 mm pa

Victoria

Area inundated by a 1-in-100-year storm surge in Gippsland may increase 15–30% by 2070. Area with at least one day of snow cover per year on average shrinks 10–40% by 2020 and 20–85% by 2050. 20–65% increase in the number of extreme fire danger days in the Bendigo region by 2020.

Melbourne

Present averages: Temp: 15.7 C; Days over 35C: 9.1; Rainfall: 654 mm pa	Projected 2070 Averages (low-emissions): Temp: 17.1 C; Days over 35C: 14; Rainfall: 615 mm pa
Projected 2030 Averages (mid-emissions): Temp: 16.6 C; Days over 35C: 11.4; Rainfall: 628 mm pa	Projected 2070 Averages (high-emissions): Temp: 18.5 C; Days over 35C: 20; Rainfall: 582 mm pa

Tasmania

21% of the Tasmanian coast is at risk of erosion and recession from sea-level rise. Strengthening of the East Australian Current may result in subtropical marine species moving into temperate waters, altering the habitat of many species. Changes in climate will favour a shift to warm-season grape varieties.

Hobart

Present averages: Temp: 13 C; Days over 35C: 1.4; Rainfall: 576 mm pa	Projected 2070 Averages (low-emissions): Temp: 14.1 C; Days over 35C: 1.8; Rainfall: 559 mm pa
Projected 2030 Averages (mid-emissions): Temp: 13.6 C; Days over 35C: 1.7; Rainfall: 571 mm pa	Projected 2070 Averages (high-emissions): Temp: 15.1 C; Days over 35C: 2.4; Rainfall: 542 mm pa

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APPENDIX A: USEFUL TERMS AND CONCEPTS

Confusion about the precise meaning of different terms used in discussions of climate change adaptation may be hard to avoid. The descriptions below provide a sense of what is common to the definitions and outlines important differences in the definitions used by different groups.

Term	Synthesis of definitions	Sources
1 in 100 flood	An event that has a 1 in 100 (1%) chance of occurring in any given year. Over a period of 25 years this type of event has a 22% chance of occurring.	Sunshine Coast Council (2012)
Adaptability	The ability, competency or capacity of a system to adapt to (to alter to better suit) climatic stimuli	Bizikova et al (2008).
Adaptation (generic):	To 'adapt' is to "make (something) suitable for a new use or purpose; modify" and "become adjusted to new conditions" Adaptation is "the action or process of adapting or being adapted".	
Adaptation (specific: climate change)	Definitions of adaptation for climate change generally refer to the definition used by the United Nations Inter-Governmental Panel on Climate Change (IPCC). Under the IPCC definition, adaptation is an "adjustment" to expected or actual changes in climatic conditions. A successful adaptation is seen as an activity that adjusts human or natural systems so that harm from changes in climatic conditions is reduced, or eliminated.	Adapted from Bizikova et al 2008, World Bank 2012, DEFRA UK 2010, Queensland Climate Change Centre of Excellence (2010), AGIC 2011.
Adaptation benefits	Avoided damage costs or accrued benefits following the adoption and implementation of adaptation measures (IPCC 2007).	World Bank (2012); Bizikova et al (2008).
Adaptation Costs	Costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs. (IPCC, 2001)	World Bank (2012); Bizikova et al (2008).
Adaptive Capacity	The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (IPCC, 2001). The adaptive capacity inherent in a human system represents the set of resources available for adaptation (information, technology, economic resources, institutions and so on), as well as the ability or capacity of that system to use the resources effectively in pursuit of adaptation (adapted from UKCIP 2003 and UNDP 2005).	World Bank (2012); Bizikova et al (2008).
AEP (Annual Exceedance Probability)	The Annual Exceedance Probability is the likelihood of occurrence of a flood or storm tide inundation event of a given size or larger in any one year, usually expressed as a percentage. For example, if an event has an AEP of 1%, it means that there is a 1% risk (i.e. probability of 0.01 or a likelihood of 1 in 100) of this event occurring in any one year. A 1% AEP event should not be interpreted as only occurring once in 100 years.	Sunshine Coast Council (2012)
Anticipatory	Adaptation that takes place before observed impacts of climate	Bizikova et al

Term	Synthesis of definitions	Sources
Adaptation	change. Also referred to as proactive adaptation.	(2008).
Baseline studies	Studies undertaken to describe the conditions that exist before an action is taken.	Australian Centre for Sustainable Mining Practices (2011),
Carbon dioxide (CO₂)	Carbon dioxide is a gas that presently makes up about 0.038 per cent of the earth's atmosphere. It is an important greenhouse gas along with water. Even though its concentration in air is tiny, carbon dioxide is an essential natural component; without it, plant photosynthesis cannot take place.	Parliament of Australia (2010)
Carbon dioxide equivalent	A carbon dioxide equivalent is a measure of global warming potential (GWP). Carbon dioxide is currently understood to have the global warming potential of 1 for every kilogram that is released into the atmosphere "over a specified period of time (usually 100 years)". Other greenhouse gases have a different amount of global warming potential, which is usually translated to an equivalent amount of carbon dioxide. For example, 1 kg of Methane is currently understood to have a global warming potential of around 25 times that of 1kg of carbon dioxide.	Parliament of Australia (2010) Queensland Climate Change Centre of Excellence (2010),
Climate	Different sources provide slightly different descriptions of what this might include or how it might be analysed. The UK's Department for Environment, Food and Rural Affairs (DEFRA) includes "temperature, wind and rainfall patterns" in a particular region. The IPCC (2001) describes this as the "mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years". The choice of thirty years as the timeframe for evaluating the 'average weather' is the definition used by the World Meteorological Organization (WMO).	Adapted from Bizikova et al 2008, DEFRA 2010, Queensland Climate Change Centre of Excellence 2010
Climate Change Adaptation:	The terms of reference for the Australian Productivity Commission (APC) have a specific definition for 'climate change adaptation' defines climate change adaptation as "action by households, firms, other organisations and governments to respond to the impacts of climate change that cannot be avoided through climate change mitigation efforts". A further distinction, between different definitions of adaptation to climate change is whether or not actions are coordinated.	Australian Productivity Commission (2011),
Climatic Hazards	include increasing frequency of extreme weather events (floods, hurricanes, tornados, droughts), increasing summer temperatures, lower level of precipitation during main growing seasons, changes in stream flow, changes in snowfall	Bizikova et al 2008, (pp. 88-92)
Consequences	The end result or effect caused by some event or action. Consequences may be beneficial, neutral or detrimental. A detrimental consequence is often referred to as an impact. May be expressed descriptively and/or semi-quantitatively (high, medium, low) or quantitatively (monetary value, number of people affected). Source: CCRA	DEFRA UK (2010),
Coping capacity	The manner in which people and organizations use existing resources to achieve various beneficial ends during and immediately after unusual, abnormal and adverse conditions of a disaster event or process. The strengthening of coping capacities, together with preventive measures, is an important aspect of adaptation and usually builds resilience to withstand the effects of natural and other hazards (adapted from European Spatial	World Bank (2012)

Term	Synthesis of definitions	Sources
	Planning Observation Network).	
Critical Threshold	The point at which an activity faces an unacceptable level of harm, such as a change from profit to loss on a farm due to decreased water availability, or coastal flooding exceeding present planning limits. It occurs when a threshold q.v. is reached at which ecological or socioeconomic change is damaging and requires a policy response. (UNDP, 2005)	Bizikova et al 2008,
Defined Flood Event	Terminology consistent with State Planning Policy (SPP, 2003) which states “Defined Flood Event is the flood event adopted by a local government for the management of development in a particular locality”.	Sunshine Coast Council (2012)
Direct risk	the chance of an impact (attributable to climate change) on an infrastructure system or organisation that causes damage, extra costs, accelerated deterioration or disruption of services provided. An example is increased storm or flood damage to infrastructure. Another example is buckling of railway tracks in extreme temperatures.	AGIC (2011)
El Nino	The South American El Niño current is caused by large-scale interactions between the ocean and atmosphere. Nowadays, the term El Niño refers to a sequence of changes in circulations across the Pacific Ocean and Indonesian archipelago when warming is particularly strong (on average every three to eight years). Characteristic changes in the atmosphere accompany those in the ocean, resulting in altered weather patterns across the globe.	BOM (2011)
Emission	Amount of substance (e.g. CO ₂) released into the atmosphere from a specific source and in a specific time frame. Emissions are generally expressed by the mass per time period (e.g. millions of tonnes (Mt) per year).	Queensland Climate Change Centre of Excellence (2010),
Environmental plantings	environmental plantings as carbon forests that are not harvested for their timber.	Wentworth Group of Concerned Scientists, 2009,
Extreme Weather Event	An event that is rare within its statistical reference distribution at a particular place. Definitions of “rare” vary, but an extreme weather event would normally be as rare as or rarer than the 10 th or 90 th percentile. By definition, the characteristics of what is called “extreme weather” may vary from place to place. An “extreme climate event” is an average of a number of weather events over a certain period of time, an average which is itself extreme (e.g. rainfall over a season). (IPCC, 2001)	Bizikova et al 2008,
Global Circulation Models (CGMs)	Numerical representation of the atmosphere and its phenomena over the entire Earth, using the equations of motion and including radiation, photochemistry, and the transfer of heat, water vapour, and momentum. (NSIDC, n.d.)	Bizikova et al 2008,
Global climate model (GCM)	Computer model designed to help understand and simulate global and regional climate, in particular the climatic response to changing concentrations of greenhouse gases. GCMs aim to include mathematical descriptions of important physical and chemical processes governing climate, including the role of the atmosphere, land, oceans and biological processes. The ability to simulate subregional climate is determined by the resolution of the model.	World Bank (2012)

Term	Synthesis of definitions	Sources
Global warming potential (GWP)	The index used to translate the level of emissions of greenhouse gases into a common measure in order to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations.	Queensland Climate Change Centre of Excellence (2010),
Greenhouse effect	An effect created by greenhouse gases in the Earth's atmosphere. These gases allow short-wavelength (visible) solar radiation to pass through to the surface and absorb the long-wavelength radiation that is reflected back, leading to a warming of the surface and lower atmosphere.	Queensland Climate Change Centre of Excellence (2010),
Greenhouse gases	Greenhouse gases are gases that contribute to the greenhouse effect in the earth's atmosphere. They are essentially transparent to incoming sunlight, but absorb heat radiated from the earth's surface, trapping this heat in the atmosphere and causing the atmosphere and earth's surface to maintain a warmer temperature than would be the case in the absence of these gases. The main greenhouse gases are water vapour and carbon dioxide. Carbon dioxide, methane and nitrous oxide are the main greenhouse gases that are increasing due to human activities. The six greenhouse gases recognised under the Kyoto Protocol are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.	Parliament of Australia (2010).
High-regret adaptation	Involves decisions on large-scale planning and investments with high irreversibility. In view of the considerable consequences at stake, the significant investment costs and the long-lived nature of the infrastructure, uncertainties in future climate projections play a crucial role when making decisions about whether to implement high-regret adaptation measures.	World Bank (2012)
Highest Astronomical Tide (HAT)	The highest predicted tide that occurs when the sun and moon are closest to the earth. Also known as the perigean spring tide or king tide. A level that closely approximates H.A.T. occurs twice a year.	Sunshine Coast Council (2012)
Highest Historical Flood Level	The highest flood water level from all historic events for which council has reliable records. Also referred to as Nominated Historical Flood Level / Known Flood Level .	Sunshine Coast Council (2012)
Hot days	Days with maximum temperature over 35 °C.	Queensland Climate Change Centre of Excellence (2010),
Indirect risk	The chance of an impact (attributable to climate change) on another system or organisation, which disrupts the direct supply of goods or services that your infrastructure system or organisation critically relies upon, thereby adversely impacting on your system or organisation. For example, power supply interruptions caused by excessive power demand during periods of extreme temperatures. Another example would be storm damage or disruption at a nearby port, which delays the delivery of urgently-needed equipment so that the infrastructure has to be closed or its services curtailed.	AGIC (2011)

Term	Synthesis of definitions	Sources
Inter-governmental Panel on Climate Change (UN)IPCC	The IPCC was established in 1988 to provide a comprehensive, objective, open and transparent assessment of the latest scientific, technical and socio-economic literature produced worldwide relevant to climate change and its risks and impacts, and options for mitigation and adaptation.	Parliament of Australia (2010)
Low-regret adaptation	Low-regret adaptation options are those where moderate levels of investment increase the capacity to cope with future climate risks. Typically, these involve over-specifying components in new builds or refurbishment projects. For instance, installing larger diameter drains at the time of construction or refurbishment is likely to be a relatively low-cost option compared to having to increase specification at a later date due to increases in rainfall intensity.	World Bank (2012)
Maladaptation	Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but instead increases it. (IPCC, 2007)	Bizikova et al 2008, DEFRA UK (2010),
Methane (CH₄)	Methane is the main component of natural gas; it is a powerful greenhouse gas with 25 times the warming effect of carbon dioxide over a 100-year time scale.	Parliament of Australia (2010)
Minimum Floor Level	The minimum floor level calculated in accordance with the applicable planning scheme. Determined through the addition of the appropriate freeboard to the relevant flood level. Also referred to as Minimum Floor Height	Sunshine Coast Council (2012)
Mitigation	A lessening in force or intensity; specifically used to describe a reduction in the source of greenhouse gases or enhancement of greenhouse gas sinks.	Queensland Climate Change Centre of Excellence (2010)
Nitrous oxide	Nitrous oxide is a colourless, non-flammable gas; it is a powerful greenhouse gas with 298 times the warming potential of carbon dioxide over a 100-year time scale.	Parliament of Australia (2010)
No Regret Adaptation Options	Adaptation options (or measures) that would be justified under all plausible future scenarios, including the absence of man-made climate change. (Eales et al., 2006)	Bizikova et al (2008); World Bank (2012)
Ozone	Ozone is a molecule which consists of three atoms of oxygen. It is toxic to animals and plants, and damages human respiratory systems. In the lower atmosphere it is a pollutant produced from emissions of other compounds during fuel combustion. However, ozone in the upper atmosphere occurs naturally and acts to reduce the amount of dangerous ultraviolet radiation reaching the earth's surface.	Parliament of Australia (2010)
Perfluorocarbons (PFCs)	Perfluorocarbons are compounds consisting of carbon and fluorine. They do not deplete the ozone layer but are very strong greenhouse gases with long lifetimes in the atmosphere.	Parliament of Australia (2010)
Planned adaptation	Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state (IPCC 2007).	Adapted from Bizikova et al 2008, DEFRA 2010,

Term	Synthesis of definitions	Sources
		Queensland Climate Change Centre of Excellence 2010, World Bank (2012)
Precautionary principle	In the Kyoto Protocol, the precautionary principle states that 'where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation'. However, it is envisaged that such measures 'should be cost-effective so as to ensure global benefits at the lowest possible cost'.	Parliament of Australia (2010)
Probable Maximum Precipitation (PMP)	The maximum precipitation (rainfall) that is reasonably estimated to not be exceeded. See http://www.bom.gov.au/water/designRainfalls/pmp/index.shtml to find out more about PMP.	Sunshine Coast Council (2012)
Regional climate model (RCM)	While global climate models (GCMs) simulate the entire Earth with a relatively coarse spatial resolution (e.g., they can capture features with scales of a few hundred km or larger), regional climate models (RCMs) downscaled from GCMs have a much higher resolution (simulating features with scales as small as a few km). Downscaling can be accomplished through one of two techniques: 'dynamical' or 'statistical' downscaling. 'Dynamical' downscaling refers to the process of nesting high resolution RCMs within a global model, while 'statistical' downscaling relies on using statistical relationships between large-scale atmospheric variables and regional climate to generate projections of future regional climatic conditions (Padgham 2009).	World Bank (2012)
Southern Annular Mode (SAM)	Refers to the north–south movement of the band of westerly winds south of Australia. SAM is positive when there is a poleward shift of the westerly wind belt and is associated with enhanced spring and summer rainfall in New South Wales and Queensland.	Queensland Climate Change Centre of Excellence (2010),
Southern Oscillation Index (SOI)	The Southern Oscillation Index (SOI) is a simple measure of the status of the Walker Circulation, a major wind pattern of the Asia/Pacific region whose variability affects rainfall in Australia and other parts of the world. During El Niño episodes, the Walker circulation weakens and the SOI becomes negative. Other changes during El Niño events include cooling of seas around Australia, as well as a slackening of the Pacific trade winds which in turn feed less moisture into the Australian/Asian region. The link between SOI and rainfall across southern and eastern Australia is strongest during the winter and spring periods (June-November). SOI values between April and September are used to produce rainfall outlooks for winter-spring rains, with low values of SOI often linked with below average rainfall in eastern Australia.	Commonwealth of Australia 2011, Bureau of Meteorology (2012)
Storm surge	A temporary increase, at a particular location, in the height of the sea, due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The excess above the level expected from the tidal variation alone at that time and place.	Queensland Climate Change Centre of Excellence (2010),
Storm Tide	Also known as storm surge, the large waves that occur when an additional surge is applied on top of the astronomical tide caused by meteorological (storm) conditions. . It is the storm tide level which must be accurately predicted to determine the extent of	Sunshine Coast Council (2012), Queensland Climate Change

Term	Synthesis of definitions	Sources
	coastal inundation.	Centre of Excellence (2010),
Stratosphere –	The region the atmosphere above the troposphere. The stratosphere is characterised by the presence of ozone and by temperatures which rise slightly with altitude, due to the absorption of ultraviolet radiation.	Queensland Climate Change Centre of Excellence (2010),
Sulphur hexafluoride (SF6)	Sulphur hexafluoride is a compound consisting of a sulphur atom and six fluorine atoms. It is a powerful greenhouse gas and is regulated under the Kyoto Protocol.	Parliament of Australia (2010)
Synthetic greenhouse gases	Synthetic greenhouse gases are industrial chemicals used mainly as refrigerant gases in air conditioning and refrigeration equipment. They are also used for foam blowing, as propellants in specialty aerosol products and in the pharmaceutical, fire protection and electricity supply industries....These gases have high global warming potentials, in the range of 140 to 23,900 times that of carbon dioxide. They can also persist in the atmosphere for many years, in one case 3,000 years or more.	Commonwealth Government (2012)
System	A group of interacting, interrelated or interdependent components forming a complex whole. E.g. Ecological systems have many components which may include soil, water and atmosphere.	DEFRA UK (2010),
Terrestrial carbon	Terrestrial carbon includes carbon stored in forests, woodlands, swamps, grasslands, farmland, soils and derivatives of these carbon stores, including biochar and biofuels.	Wentworth Group of Concerned Scientists, 2009,
Troposphere	Described as the area between the Earth's surface, and the stratosphere (an altitude of about 8 kilometres over the poles, and to about 16 kilometres over the equator). This area is understood to be the part of the atmosphere in which "...nearly all cloud formations occur and weather conditions manifest themselves' The troposphere extends from the surface upwards. It contains three-quarters of the atmosphere's mass. The continuous movement of air within the troposphere (and the cooling as air rises) creates clouds and rain; thus the troposphere is the layer where most of the world's weather takes place.	Queensland Climate Change Centre of Excellence (2010), Parliament of Australia (2010)
Vulnerability	The level of risk that remains once the potential impacts of climate change have been addressed as much as possible by adaptation.	AGIC (2011)
Weather:	Most sources define 'weather' as being the state of the atmosphere, including temperature, air pressure, humidity, wind, cloudiness, and precipitation" and "other meteorological conditions" at a particular place at a particular time.	Adapted from Bizikova et al 2008, DEFRA 2010, Queensland Climate Change Centre of Excellence 2010
Very hot days	Annual count of days with maximum temperature > 40°C	BOM Extreme Temperature Indices accessed 25 th Sept 2012
Hot days	Annual count of days with maximum temperature > 35°C	"

Term	Synthesis of definitions	Sources
Very hot nights	Annual count of nights with minimum temperature > 25°C	"
Hot nights	Annual count of nights with minimum temperature > 20°C	"
Cold days	Annual count of days with maximum temperature < 15°C	"
Very cold days	Annual count of days with maximum temperature < 10°C	"
Cold nights	Annual count of nights with minimum temperature < 5°C	"
Frost nights	Annual count of nights with minimum temperature < 0°C	"

National Climate Change Adaptation Research Facility
Griffith University Gold Coast Campus
Parklands Drive, Southport
QLD 4222, Australia
Telephone 07 5552 9333
Facsimile 07 5552 7333
www.nccarf.edu.au



Australian Government
Department of Climate Change
and Energy Efficiency



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