Climate science in mine water system design

Jennifer Ahern[1], Mark Gibbs[2]

[1]*AECOM, Level 8, 540 Brunswick Street, Brisbane, Australia, Jennifer.Ahern@aecom.com*
[2]*AECOM, Technical Director, Level 8, 540 Brunswick Street, Brisbane, Australia, Mark.Gibbs@aecom.com*

Abstract

Water inflows into mine sites is a key parameter to consider when designing infrastructure for mine site water management. Hence uncertainty in inflows presents a key risk that needs to be carefully managed. In particular, both the magnitude and frequency of high-intensity, extreme events needs to be understood to avoid designing and constructing over-capacity water infrastructure. The science and engineering professions have long known about the importance of understanding variability in both surface and groundwater inflows and have developed robust approaches for developing these key design parameters. However these approaches are generally, if not exclusively, based on historical data from the site when available or from regional data sources and relationships.

By contrast, the climate science community has advocated that future environmental conditions may, in some cases, be different to the conditions over the last 100 years — the typical period which is used to develop design inflow parameters. While climate science has suggested, if not demonstrated, a high likelihood of different climatic conditions in the future, it is unable to produce an accurate time series of future inflow conditions. This uncertainty leads to a plethora of issues ranging from how to methodologically deal with uncertainty in design, including regulatory design requirements, to how to manage the risk of this uncertainty from an infrastructure financing and insurance perspective.

This paper demonstrates the need for a more risk informed approach to developing design parameters as a result of inherent uncertainties in future climatic conditions that will not be resolved in the short term through improved climate projections, and will present an overview of one method to manage climate uncertainty with particular reference to the current state and future uncertainty in climate projections.

Keywords: climate change, mine water management, risk based design, water balance

Introduction

Rainfall and runoff are key input parameters used when designing water management infrastructure for mine sites. The primary tool for designing water management infrastructure is a water balance; often taking the form of a probabilistic assessment based on historical data and projected site operations. A water balance can be used to determine the likelihood of:

- inflows to the site being able to supply operational demands

- the water management system having capacity to store inflows, caused by intense rainfall events during the wet season.

The consequences of a site not being able to meet operational demands could range from employing water saving techniques to lengthen supply, purchasing and importing expensive and often scarce water resources and, in the worst case, shutting down operations.

The consequence of a site water management system not having capacity to deal with storm water runoff can range from non-compliance to environmental licence conditions due to uncontrolled discharge to flooding of open cut pits and draglines. This has recently been experienced in Queensland, with many mines declaring Force Majeure on supply contracts due to weather interference. Ultimately having not enough or too much water can lead to economic losses.

Currently the accepted practice for water balance assessments is to use approximately 100 years of historical rainfall data. However climate science tells us that the previous 100 years of rainfall is not necessarily representative of the future. Projections of Global Climate Models (GCMs) indicate the central Queensland region will likely experience a decline in average rainfall, while an increase in the intensity and frequency of extreme rainfall events is also predicted Department of Environment Resource Management (2009b). This has the potential to impact both water supply and mine flooding.

Even through the use of GCMs, exactly what the future climate will look like remains uncertain. This uncertainty is due to a number of factors, the primary factor being uncertainty in future greenhouse gas emissions. Climate scenarios describe six possible future climate states, depending on economic, demographic and technological factors as described in Intergovernmental Panel on Climate Change (2007). The IPCC states 'It is our view that there is no objective method of assessing the likelihood of all the key assumptions that will influence the future emission estimates … Thus we do not attempt to identify the most likely emission scenario' (Mitchell & Hulme 1999, p.57-78).

So the question is how can climate change be incorporated into the design of mine water management systems, while still accounting for the uncertainty inherent in predicting climate change?

Risk Based Approach

One methodology, proposed by Gibbs (2011, p.1-6) is to use a risk-based approach. Risk is defined as the product of consequence and likelihood. There is no difference in consequence for a lack of water supply or flooding of a mine site between the various climate change scenarios. In each case, economic losses will be incurred. It is the likelihood of events causing these consequences which remains uncertain.

Using a case study, this paper presents one approach to assessing the probability of the impact of climate change on key parameters which are used in the design of mine water management systems.

A Case Study: Bowen Basin Coal Mine

This case study is based on a coal mine in the Bowen Basin, central Queensland. The mine is within the Fitzroy River catchment. The site has a historical average annual rainfall of approximately 640 mm and an average annual site demand of 1.3 GL. The site is currently licensed to discharge under controlled conditions.

The water balance for the mine site simulates storage, rainfall, runoff, groundwater, evaporation, seepage, operational demands and current discharge conditions. It is assumed that groundwater, evaporation, seepage and demands remain constant for the climate scenarios.

For this investigation, three GCMs predictions for rainfall were evaluated and compared against historical data. The GCMs were chosen based on their ranking according to Perkins et al. (2007, p. 4356). The ranking is based on a simple quantitative measure of how well each climate model can capture the observed probability density functions for rainfall in the region of interest (Perkins et al. 2007). The three top ranking GCMs are:

- BCCR: Bjerknes Centre for Climate Research, University of Bergen, Norway
- ECHAM: Max-Planck-Institut für Meteorologie
- ECHO-G: Meteorological Institute of the University of Bonn

OzClim was used to determine the percentage change of rainfall from baseline values for each season for the three GCMs. OzClim is an online tool developed by the CSIRO which is used for projecting climate for a range of emission scenarios. The scenario adopted for this investigation was based on:

- year 2040 (30 year design life assumed)
- high rate of global warming
- emission scenario A1FI, defined as fossil fuel intensive with rapid economic and technological growth (IPCC 2007).

Table 1 shows the percentage change in rainfall as a result of the above scenario.

Table 1 *Percentage change in rainfall from baseline climate to 2040. Source: CSIRO (2007)*

Global Climate Model	Summer	Winter	Autumn	Spring	Average Annual Rainfall*
1 BCCR	-8.2%	15%	-7.1%	-12.3%	-4%
2 ECHAM	-0.7%	-4.9%	3%	-15.8%	-4%
3 ECHO-G	10.8%	8.4%	2.7%	-9.2%	5%

*based on historical data

Rainfall and runoff data for the historical and three climate scenarios were run through the water balance model for the site. The water balance ran 100 realisations of 30 years using the Monte-Carlo probabilistic method, as recommended by Gibbs (2011, p.1-6).

Results and Discussion

The results showed that in the historical and climate scenarios, the mine did not incur a notable deficit. This is expected as the site currently has very little water demand and there have not been supply deficits experienced historically.

The results in Table 2, 3 and 4 show the percentage changes from baseline values for rainfall and runoff inflows, peak system volumes and release volumes. The results are described in percentiles, with the 95th percentile indicating that a parameter has a 95% probability of being at or below a given value and a 5% probability of exceeding the value.

The results in Table 2 indicate the percentage increase or decrease likely as a result of the three modelled climate scenarios. The results show that there is a 99% probability that the change in total rainfall and runoff inflows will be between -3% and 7% from the baseline.

Table 2 *Percentage change of runoff from baseline values*

Global Climate Model	20th percentile	50th percentile	95th percentile	99th percentile
1 BCCR	-4%	-4%	-3%	-3%
2 ECHAM	-5%	-4%	-4%	-4%
3 ECHO-G	5%	6%	6%	7%

The results in Table 3 show the change in peak system volumes compared to baseline values. Typically, peak system volumes are used to design the minimum capacity of the water management system to accommodate excess water from mine operations. For example, the system may be designed to a 95% reliability, which means that the operational storage volume for the system would have a 5% probability of being exceeded. The results show that based on the three climate change scenarios modelled, a system designed for 95% reliability based on historical data may be over designed by 2% or under designed by 3%. This range is exacerbated as the design reliability of the system is increased.

Table 3 *Percentage change in peak system volumes from baseline values*

Global Climate Model	95th percentile	99th percentile	Greatest Historical Results
1 BCCR	-2%	-3%	-2%
2 ECHAM	-1%	-2%	-4%
3 ECHO-G	3%	2%	5%

Given this is a discharge site, the results in Table 4 show the change in total release volumes from baseline values. The results show that there is a 99% probability that releases will vary between -6% and 13% of historical release volumes. This result may have important consequences on the licensing of discharge conditions, which is currently based on recommendations provided from a study of the cumulative impacts of water discharges from mine sites on the health of the Fitzroy River (DERM 2009a).

Table 4 *Percentage change in release flows from baseline values*

Global Climate Model	80th percentile	95th percentile	99th percentile
1 BCCR	-7%	-6%	-6%
2 ECHAM	-7%	-6%	-6%
3 ECHO-G	12%	13%	13%

Conclusions

For this case study, the assessment of climate change impacts on key parameters affecting mine water management has concluded that while inflows may vary notably, in the range of -4% to +7%, water supply is not affected in this case; due to low demand for water. The range of peak system volumes may vary by -3% and 2% for a design of the system reliability of 95%, which is unlikely to result in a significant difference in constructions costs. The relatively insignificant variation in peak system volume is most likely due to the significant change in release flows from the sites, which ranges between -6% and 13% compared to baseline values. This may have significant impacts on the health of the Fitzroy River, as release conditions are currently based on a cumulative impact assessment which uses historical data as its basis.

Further Investigations

In addition to the assessment presented in this paper, the following are a few of the further investigations which could also be undertaken:

- the range of different emission scenarios
- the effect of climate change beyond 30 years
- the impact of climate change on evaporation and groundwater
- the impact to a no-discharge site

Acknowledgements

We would like to thank Edith Cowan University for hosting the IMWA 2012 Conference. We would also like to thank Silver Yance for reviewing this paper and Chris Barnes and Tahnee Kruse for their contributions.

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