Mine Water – valued resource or missed opportunity?

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Abstract For mining operations in Australia, water is an essential element that affects operational viability. Too little constrains production; too much can prevent access to orebodies and require release. Achieving a balance is difficult, particularly in open cut mining operations.
Climatic extremes present two key challenges, being:

- Sourcing water during periods of deficit.
- Managing mine water during periods of excess.

Water supports a range of economic and community benefits, but are we realising maximum value across a mines' lifecycle? Why are these opportunities being missed – Is it attitudinal, water quality, availability, regulatory or pure economics that is limiting us?

Keywords mining, economics, agriculture, regulation, climate

Introduction

The Australian climate is typified by climatic extremes. For eastern Australia, this is predominately driven by the long term cycles as a result of the movement of warm water across the Pacific Ocean between the Americas and Asia / Australia, known as La Nina and El Nino. Water is a key input for agriculture and mining operations to support production. Climatic variability presents challenges to mining operations which can affect their viability. Within the Bowen Basin, mining and agriculture rely on the same water sources.

Mining operations also generate and release excess volumes of Mine Affected Water (MAW) to the environment. MAW occurs as a result of rainfall and runoff within disturbed catchments, or as a result of aquifer dewatering in advance of mining. MAW is typically stored in disused pits until it is able to be reused or release.

Mines are located adjacent to agriculture. There is potential for greater economic and community benefits as a result of better water management and use, particularly within the context of a highly variable climate. This paper explores these benefits, as well as the barriers to them.

Geographical and Climatic Context

The Bowen Basin, located within Central Queensland in Australia, produces approximately 160 Million Tonnes Per Annum (MTPa) of coking and 58 MTPa of thermal coal. Annual rainfall varies depending on distance from the coast, however is typically 600-800mm per annum. Evaporation is far greater, being 2,000-2,500mm per annum. Rainfall varies depending on the La Nina / El Nino cycle which drives the climatic extremes. Recent examples are the 2001-07 drought (El Nino) which was broken by successive years of above average to highest on record rainfall, resulting in flooding from 2007 to 2011.

Nearly all of the mines within the Bowen Basin are within the Fitzroy River catchment, comprised of the Isaac and Connors Rivers in the north, the Nogoa-McKenzie to the central-west, and the Dawson River in the south, and draw water from this system. Additional supply is sourced from the Burdekin River and associated tributaries and pumped to mines within the Bowen Basin. The Nogoa-Mckenzie River has a maximum annual water allocation of 255,000 ML/a (DNRM, 2015), whilst the Burdekin (below Burdekin Falls Dam) has an annual maximum allocation of 235,000 ML/a (DNRM, 2011).

Agriculture is the predominant land use, with irrigated cropping being of similar extents to mining. Carrol *(eWater CRC, 2004)* summarised the catchment landuse as comprising:

- Grazing: >13 million ha (130,000 km^2).
- Dryland cropping: approximately 0.8 to 1 million ha (10,000 km^2)
- Irrigated cropping: 45,000 ha (450 km^2).
- Open cut coal mining: > 50,000 ha (500 km^2).

Towns and communities are scattered throughout the Basin. These towns, the agricultural users and mining compete for land and water.

Water Sources, Quality Requirements, and Regulation

Mining

Mines utilise diverse water sources which typically include at least two of the following:

- Surface water runoff from disturbed catchments within the mines – known as MAW,
- Groundwater from dewatering and aquifer depressurisation – also known as MAW, and
- Raw water sourced from water supply borefields, dams and weirs, and delivered to site via pipelines – known as raw water.

Mining operations use water that is generated onsite for coal processing, dust suppression and other mining related activities. Each site is however reliant on raw water from 'clean' sources that have not been contaminated. This is due to operational requirements to support mining activities and for potable uses. Under current legislation and drinking water standards (Queensland Water Supply and Security Act (2011) and the Australian Drinking Water Guidelines (2015)), MAW cannot be used as a source for potable due to potential health risks.

The quality of MAW is dependent on the contributing catchments and associated geochemistry. The quality of groundwater varies depending on aquifer conditions. Water quality varies depending on the catchment, the time it has been stored for, and changes in quality due to evaporation. Typically, MAW ranges from a pH of 6.0 up to 9.0, and Electrical Conductivity (EC) of 4,000 to 15,000 uS/cm.

To comply with their Environmental Authorities (EA)'s (which govern the mining operations and the permissible activities), mines are required to retain all MAW and store and/

or reuse this water. The ability to discharge MAW from each mine is dependent on their respective EA, but most mines have conditions and performance criteria which permit the release of MAW and excess water generated from rainfall events receiving waters. These releases are permitted only when receiving waters have sufficient streamflow to dilute the water being released, with upstream and downstream monitoring.

Most EA's have an end of pipe maximum water quality limit of 10,000 µS/cm EC and pH of 8.5 for releases from the mines. The volume that is released is dependent on streamflow, and downstream water quality limits range up to 2,000 µS/cm EC. The current release arrangements have been in place since 2012 following the 2011 flood event. This provides a workable framework for mining operations to achieve release and reduce their MAW inventories.

MAW is typically reused unless its EC exceeds suitable limits. This varies between coal mining operations, but once the water quality exceeds release limits of 10,000 µS/cm, it is unable to be used due to impacts on coal processing, mining fleet and on the composition of the coal product.

Releases are monitored by the Queensland Department of Environment and Heritage Protection (DEHP). Mines are required to notify DEHP immediately once releases occur, with current release data being published online during the period of release. Totals of historic releases are however not publicly available. Based on observations of recent events for FY16, release volumes have been estimated to total 4,100 ML for 23 of the total of 51 recorded releases. The observed quality varies from 500 µS/cm up to 10,500 µS/cm. The location of the releases are principally from mines within the Isaac and McKenzie – tributaries of the Fitzroy River.

Agriculture

Board acre cropping of pulses, grains and cotton typically rely on rainfall and are supplemented by irrigation. Water is sourced either from groundwater aquifers under licence or large irrigation schemes, such as Fairbairn Dam on the Nogoa River and its associated downstream weirs. Within this irrigated scheme, crops including cotton, peanuts, chickpea, and corn are grown, with horticulture producing citrus, table grapes, and melons. Water from dams and weirs is typically low in salts (EC at or below 200 µS/cm) and which is ideal for supporting agriculture.

Interrelated legislation defines the suitability of various sources and its quality for cropping. Regulations permit the use of high EC water, however use of high EC and specifically mine affected water is restricted to pasture and tree crops. This is a human health requirement, and prevents the use of mine affected water for horticulture.

Within Queensland, water produced as part of coal seam gas (CSG) operations is of a similar quality. The Coal Seam Gas Water Management Policy (DEHP, 2012) with supporting legislation and referenced Acts requires proponents to achieve beneficial reuse of this water or reinjection of the water. This was implemented to mitigate the open storage of CSG water and evaporation in lieu of use for beneficial purposes. A key difference for CSG water is that it is regarded as a waste first and foremost. The Policy does permit use of CSG water for drinking water purposes, however the potential risks and impacts must be understood and sufficient treatment barriers implemented. Beneficial reuse, such as agriculture, is encouraged.

Whilst not specifically applied to coal mines and reuse of water from coal mining operations, it could be assumed that this or similar legislation would be applied to mining as the source and quality of the water is similar.

Communities

Numerous communities rely on water sourced from surface water sources or from groundwater. Major towns (>1,000 persons – Emerald, Blackwater, Middlemount, Moranbah, Moura, Dysart) rely on the same surface water sources that supply mines.

Under the Water Supply Security and Health Act (2011) MAW cannot be used as a water source.

Even if the water were appropriately treated, community attitudes regarding where water is sourced from may limit its use due to perceived quality and health risks.

Indirect reuse of MAW does currently occur when discharges from mines occur during major streamflow events. However, there is a high level of dilution, with the relative volume of the controlled MAW discharges being far less than the diffuse sources from agricultural operations, which comprises the majority of the landuse and therefore streamflow within the Fitzroy River. Tension exists between mines and agriculture regarding the source of pollution within the Fitzroy River, which is ultimately affecting the health of the Great Barrier Reef.

Demands and the impact of Climatic Variability

Water Demands

Limited data is available for raw demands associated with coal production for individual mine sites, as this information has historically been regarded as ‘commercial in confidence’, and difficult to source in a consolidated manner. Evans (2003) suggested that ‘approximately 200L of fresh water (raw water) can be consumed for every tonne of coal produced, although that can vary both upwards and downwards according to operating practice and circumstances’.

The demand for raw water does not necessarily account for the total water demand onsite. For the purposes of comparison, a raw water demand of 200 L/tonne has been adopted.
In Financial Year (FY) 2014-2015, the Bowen Basin produced 218.62 MT of coking and ther-

mal coal. This translates to a raw water demand of approximately 43,723 ML/annum. When compared to the total allocations of 247,000 ML/annum (Nogoa-McKenzie River – Fitzroy River System), and the 235,000 ML/annum (Burdekin River), mine demands are relatively small, representing less than 10% of both sources' maximum available allocations.
The mines and townships hold 'high priority' water allocations, which are higher cost but also more reliable. During periods of extended drought, lower priority allocations (which are typically held by agricultural users) are reduced. This means the value of water increases, but also the extent of land under cropping decreases, impacting farming operations.

For agriculture, water demands vary depending on the prevailing seasonal conditions. Broadacre crops are heavily reliant on rainfall and are supplemented with irrigation (e.g. wheat, sorghum, cotton) whilst horticultural crops such as citrus are highly irrigation dependent. Accounting for typical seasonal rainfall of 200mm, only high intensity crops require additional water to support growth. Wheat is successfully grown as a broadacre crop relying only on rainfall. A lack of rainfall leads to smaller yields, but crop success.

The typical water demand and yield for specific crops is summarised Table 1 below.

Table 1 *Crop Water Demands (Total and Seasonal) vs Yield*

Crop Type	Total Water Demand (Typical)	Seasonal Water Demand	Yield	Data Source
Wheat	3 ML/ha	<1 ML/ha	4.5 t/ha	Dept Agriculture and Fisheries Qld (2012)
Cotton	5.4 ML/ha	3.4 ML/ha	1.9 bales/ha	Australian Cotton (2012)
Citrus (Oranges)	5-8 ML/ha	3-5 ML/ha	40-50 t/ha	Growcom (2001)

Using the FY16 release volumes of 4,100 ML for 23 release events (ignoring quality and storage limitations) and adopting the Seasonal Water Demand, an additional 18,450 tonnes of wheat, 2,291 bales of cotton, or approximately 41,000 tonnes of citrus could have been produced.

There are limitations on the use of MAW, particularly for citrus. EC levels of 400-700µS/cm in sandy and loam soil represent the limiting quality parameter for citrus. Similar limitations for wheat and cotton are likely to occur.

Climatic Extremes and Variability

Climatic extremes are dependent on the La Nina / El Nino cycle. The most recent climatic extremes were the 2001-07 drought (El Nino) which was broken by record successive years of above average to highest on record rainfall, resulting in flooding from 2007 to 2011 (La Nina).

Since 2011, the prevailing climate has been neutral, with neither strong La Nina or El Nino events occurring. This doesn't mean that climatic extremes and variability haven't occurred.

By comparing the recent historic rainfall with historic median, the 10% dry and 90% wet suggests that from 2012 to 2014, annual rainfall was close to average, with 2015 being drier than average and approaching 10% dry. Recent historic data is presented in Table 2.

Table 2 *Moranbah: Historic Rainfall (2012 to 2016)*

Year	2012	2013	2014	2015	2016
Rainfall (mm)	426	590.4	549	459	1036
Median (mm)	607	10% Dry (mm)	375	90% Wet (mm)	883

Further interrogation of recent historic climate suggests a highly variable climate, with intense rainfall events and extended periods of dry weather, including unseasonal rainfall. The monthly rainfall vs recorded monthly historic median and percentiles is presented in Figure 1.

As shown in Figure 1 the recorded rainfall has been below median for most of 2015, approaching or being at the 10% Dry recorded levels (i.e. very dry). In 2016, there were major rainfall events in January and December, and unseasonal rainfall in June-July. The intervening periods were generally well below median.

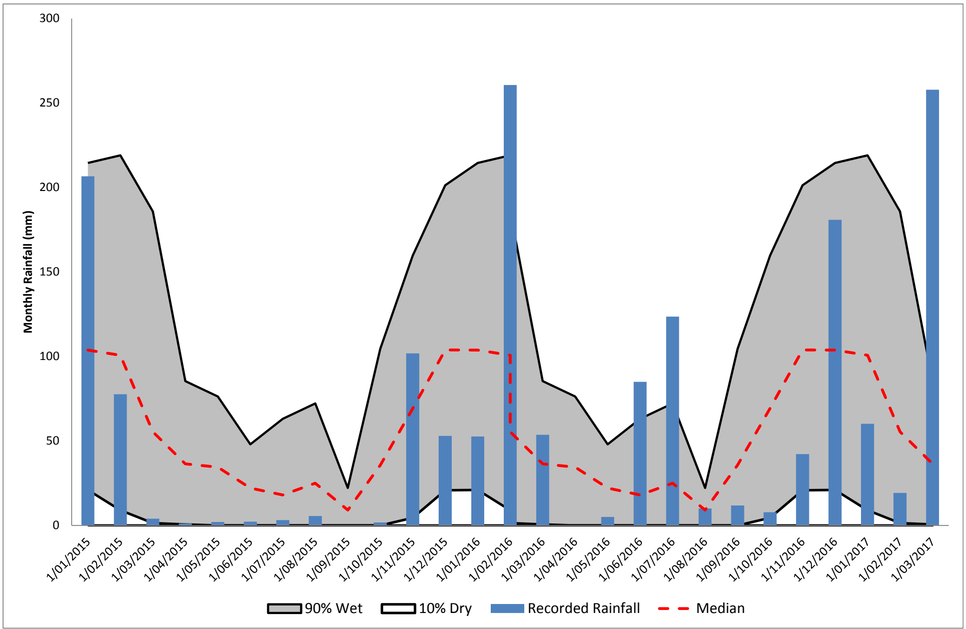

Figure 1 *Moranbah: Historic Rainfall by month vs Median and Percentiles (2015-2017)*

The variability of climate could be regarded as typical, however the rapid changes between wet and dry, and scale of rainfall events, including seasonality, creates challenges for managing water on mine sites, and capturing MAW for other purposes. The recent climate is considered to be representative of the challenges faced by mining operations, and the potential opportunities.

Challenges and Opportunities

There are a range of challenges and opportunities associated with climatic variability.

- **Water Quality:** From a physico-chemical perspective, and ignoring regulatory issues, the ability to use water from mines depends on the ability to collect and store MAW, and maintain its quality to ensure its suitability and availability for reuse. This is difficult, as most MAW catchments feature spoil or tailings; and the storages themselves are invariably disused mine pits with direct aquifer connections. The water chemistry within these disused pits is also not well understood.

- **Cost – Capital and Operational:** the irrigation schemes within the Fitzroy and Burdekin Rivers were established using Commonwealth and State funds to establish viable agricultural industries. Water from these schemes have a relatively low operational cost. The capital has largely been sunk into these schemes, and the low cost of water enables margin creation from the crop being grown. Extensive irrigation infrastructure would be needed to enable agricultural use of MAW. Whilst not expected to be completely cost prohibitive, when other sources of water are low cost, high cost water will not be used.

- **Regulatory Environment:** the regulatory environment is reasonably advanced for the use of MAW for other purposes, but MAW use is limited to within mines, or for release to the environment. Within Queensland, there are currently no mines that sell or give away MAW to third parties for use as a disposal method. This is due to current EA's restricting mines from transferring water off lease, even if this is to another mine. Changes to these arrangements require renegotiation of the EA's, which could expose mines to stricter operating conditions. This means the mines are unwilling to explore beneficial reuse schemes due to the potential regulatory consequences. As demonstrated within the CSG industry, developing water reuse schemes is possible when necessary to meet regulatory requirements. However as mines can release water without amending their EA's, it is unlikely that schemes would be developed.

- **Attitudinal:** the primary focus of mining operations is to produce coal as cost efficiently as possible. Creating and storing water is not be regarded as 'core business', amending an EA could be high risk, and as there is no business or regulatory imperative, this would not typically be undertaken. Even where individual corporations have identified economic or social values and potential benefits from using the water, decisions are conservatively made so as not to risk impacting core business of mining.

- **Community:** the attitudes of the local community are important to the acceptance of MAW for alternative uses. There have been issues associated with the use of highly treated wastewater as an indirect potable resource. MAW does not carry the same perception, however it is regarded as 'dirty' or contaminated. Therefore, whilst it could be perfectly suitable in some instances, community concern would likely limit is use to non-food crop purposes.

Conclusion

Whilst there are a range of limitations and challenges to the use of MAW, there is no single reason rather a combination of issues. The use of MAW is not a necessity for agriculture; other sources of water are cheap and readily available; and the regulatory environment presents its own challenges. Therefore, it is not likely that the use of MAW will occur in the near future.

Despite the current constraints for offsite beneficial reuse of MAW there are opportunities. These are:

- **Preventing water becoming MAW in the first place:** by reducing contributing catchments via diversion or rehabilitation (subject to regulatory approval), less volume would require storage prior to release. This in turn would lead to greater freshwater runoff that could be extracted downstream by other users.
- **Reducing raw water demands by maximising MAW use:** allocations that are currently held could be reduced or eliminated and made available for agriculture if MAW use was maximised in a sustainable manner. This would require consideration of long term availability and risk. If this occurred, more high security water would become available for other uses such as agriculture and other high value customers.

The ability to achieve these improvements depends on how well mining operations understand their water requirements and how it varies with climate within an ever changing disturbance footprint, and the associated risk to operations.

Of the potential causes of missed economic and community benefits across a mines' lifecycle, it is considered that the attitudes of mines and the community are the root cause. Water isn't valued highly enough as a commodity to change attitudes which would in turn change regulations and drive economics. The CSG industry in Queensland demonstrates how regulations can drive actions, and how beneficial reuse schemes can achieve benefits, but strong drivers do not currently exist.

Post-mining the ability to use voids needs further consideration, recognising the intent of closure is to achieve a stable landform that requires no further ongoing management or maintenance, with stormwater runoff at a suitable quality resulting in no legacy issues.
There is potential to realise community and economic benefits – it is a matter of valuing the resource appropriately and creating the right opportunities for use.

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References

Australian Bureau of Meteorology (2017) Climate Data Online. Bureau of Meteorology.

Water Planning (North) Department of Environment and Resource Management (DERM) (2010), Burdekin Basin Resource Operations Plan December 2009 Amended October 2010 Revision 2.

Water Policy—Department of Natural Resource and Mines (2015) Fitzroy Basin Resource Operations Plan September 2014 Amended September 2015. State of Queensland.

Carrol C (2002) Fitzroy River – Catchment Characteristics. eWater Cooperative Research Centre for Catchment Hydrology.

Evans R, Roe P and Roy R (2003) Water Use and Sustainable Development in Coal Mining – A Case Study from Central Queensland. Sustainable Minerals Institute, UQ and BMA Coal.

Growcom (2001). Water for Profit Benchmark – Irrigating Citrus. Growcom, Department of Primary Industries and the National Centre for Engineering in Agriculture

Cotton Australia (2007). Water use efficiency in the Cotton Industry. Cotton Australia Pty Ltd.

Department of Agriculture and Fisheries (2012) Wheat – Planting Information. Department of Agriculture and Fisheries, State of Queensland.

Department of Environment and Heritage Protection Government (2012) Coal Seam Gas Water Management Policy. Department of Environment and Heritage Protection