On the Establishment of Acceptability Criteria for Subsidence Impacts on the Natural Environment

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Summary

Every new underground coal mine in NSW, or extension to a mine, has to have some form of environmental assessment study. Such studies must determine the likely impacts on the natural and built environments.

Criteria for the built environment, such as houses, roads, rail, communications and power lines, have been established over the years, or are established for specific projects by relevant authorities. These matters are not without dispute, particularly in respect to private homes, but are not the subject of this paper.

The issue dealt with herein is that criteria for protection of the natural environment do not exist, probably because they are strongly subjective. The extremes of subjective views range from those for whom any creek, swamp, tree or frog has intrinsic value so great that no disturbance is acceptable, to those for whom the economic and postulated societal benefits from mining far outweigh other considerations.

Our society must find a reasonable path between these extremes. To date many consider that we have not done a good job, from both the technical and political viewpoints.

This paper gives consideration to the impacts of mining on the natural environment under the following categories:

- Groundwater systems
- Swamps
- Water quality in streams
- Cliffs

The paper suggests criteria to be applied, or issues to be addressed, in finding the greatest common benefit when assessing mining proposals, and reviewing the progress of mines operating in sensitive environments.

While the viewpoints expressed in this paper are substantially influenced by experiences in the Southern and Western Coalfields, it is suggested that the concepts have wider applicability.

1. The background

1.1 Cliffs

In 1931 the 200m high cliff at Dogface Rock in Katoomba collapsed, depositing about 100,000 cubic metres of rock in the valley below. In late 1965 a cliff of similar height started to topple and collapse at Nattai North, and by 1985 about 14 million cubic metres of rock had tumbled down towards the edge of Warragamba Dam. Both were due to subsidence impacts associated with underground coal mining, but in those times this was well hidden and the public either did not know or did not care. The 'thousands of people who saw the Dog Face Rock go over' were more concerned about whether they would be 'cheated of another thrill by darkness when the millions of tons of rock in the main cliff' collapsed (Evening News 28 Jan 1931, p 5).

There have been many other cliff collapses associated with coal extraction, and they continue to this day – now they are an issue but subject to questionable criteria of acceptability or unacceptability (Waddington & Kay 2002). Thus we have the 2009 Environmental Assessment for Ulan

Mine Extensions stating explicitly:

- *'Subsidence induced rockfalls are expected in 10% to 20% of the numerous sandstone cliffs above the mining areas. 70% of cliffs are expected to show perceptible changes (cracking).'* (SCT 2009)
- *Most of the cliffs, 20m or higher, above the mining area 'are expected to experience the full range of subsidence movements and all are expected to have a high probability of rock falls because of their height and continuous nature.'* (SCT 2009)

The cliff lines in Sugarloaf State Conservation Park were assessed (Dutton Geotechnical Services, 2010) using the system given in Table 1, with the following conclusions:

> *The results indicate that the cliff's mining impact rating is* ***'Very High'*** *to* **'Extremely High'***; the aesthetics and public exposure impacts is* ***'Very Low'*** *to* ***'Insignificant'****; with natural instability having a '****Low'*** *impact. The overall impact rating is* ***'Moderate'*** *after consideration of all three impact categories.*

When cliffs actually collapsed in 2013, and came to the attention of the public, there was substantial outcry. Pictures were splashed across the media and did the mining industry no service.

1.2 Rivers

In 1994 significant cracking occurred in the bed of the Bargo River above longwalls of Tahmoor Colliery, and in 1996 the bed of the Cataract River was found to be cracked; water was lost from some swimming areas used by the public, methane bubbled from many places and the water quality deteriorated. A Mine Warden Inquiry found that this was due to subsidence associated with longwalls of Tower Colliery that passed beneath the gorge of the river.

Since that time similar cracking has occurred in the upper Georges River, in the Waratah Rivulet and other watercourses in the Special Areas, through swamps above Springvale Colliery, and in small creeks above the Ulan, Wombo and West Wallsend collieries. Partly because the cracking is obvious, and occurred in Sydney's drinking water catchment or places that were used by the public for recreation (see Figure 1), the outcry has been substantial. It has led to some mining companies, such as Illawarra Coal, replanning longwall layouts so as not to mine beneath the gorges of the Nepean River and its major tributaries. However, there is no specific planning policy regulating the allowable impact on stream beds.

Figures 1a and 1b **Cataract River 1975 and 2005**
The water has the milky green signature of iron spring contamination
Note that 2005 was towards the end of a significant drought period

1.3 Swamps

At a workshop set up by the Sydney Catchment Authority in July 2013, at which many specialists involved with assessment of mining impacts in the Southern Coalfields were present, it was accepted – finally, some may say – that certain longwall mining in the Southern Coalfields had caused drainage of water from upland swamps, which are listed as Endangered Ecological Communities (see Figure 2).

Damage to a swamp system on the Newnes Plateau above another colliery – whether due to subsidence-induced drainage or to discharge of mine water, or both – occurred above longwall mining. This swamp was listed under Commonwealth legislation as an Endangered Ecological Community, but this did not prevent mining directly below it. Now, undermining of swamps listed under the EPBC Act requires direct ministerial approval. The potential impact on such swamps, via impacts on the groundwater regime has long been a matter of contention, and as of the present time there are no criteria that balance environmental considerations against the indisputable economic value of the coal.

It is understood that a 2013 report to the Federal Government into impacts on upland swamps, by the Water Research Laboratory of University of NSW, found that swamps were adversely affected in 100% of cases reviewed, and that there exists no feasible remediation strategy.

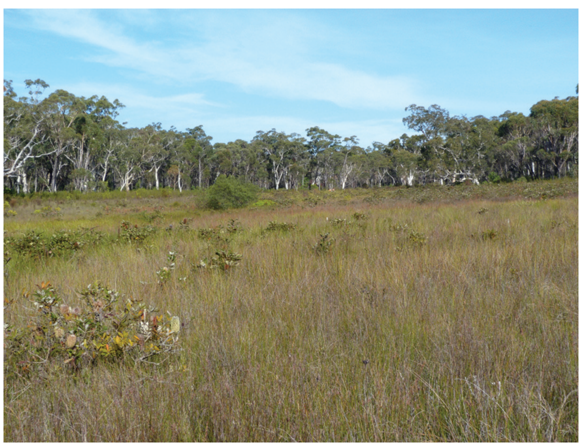

Figure 2 **Typical upland swamp Southern Coalfields**

1.4 Groundwater

In 2007 a commercial chicken farmer on Barbour Rd, Thirlmere, who relied upon bore water to feed and cool his chickens, lost about 90% of the yield of his bore (Tahmoor Colliery 2008, 2009 and 2010). This occurred at the same time as Tahmoor's Longwall 21 passed, not beneath, but close to his property. The owner was very upset, made his feelings known, and the colliery connected town water to his property. The company then drilled a new, deeper bore, but it yielded limited, heavily iron contaminated, water. So as of 2011 he was still using town water.

Meanwhile, nearby, a specialist vegetable farmer, a recent migrant from Cyprus, lost his bore water. He raised the issue with the authorities, who visited his site and told him that it could not be due to mining as there was none near his property. He gave up at that point and paid for water. The truth is that Longwalls 20 and 21 are directly beneath his property. Unbeknownst to him, only about 400m away, yet another landowner was having water trucked in by the Mine Subsidence Board to irrigate that farmer's orchard, because he too had lost all his bore water.

We have given the above examples to illustrate the tensions that exist between the economic value of coal won by longwall methods and the natural environment, and so to lead in to consideration of criteria that could be applied to impacts on some of these landform features and water resources.

2. The debate

2.1 General

The debate rages on as to whether longwall mining causes unacceptable impacts on surface and near-surface groundwater systems, and stream baseflows. The key word is 'unacceptable'.

In approving the Illawarra Coal Dendrobium mine's Area 3B, the Director-General for Planning and Infrastructure wrote: *'Fundamental to my decision was to ensure that there would be no **unacceptable** impacts on Sydney and Wollongong's water supply.'* **(our emphasis)**

The reality is that mining competes for priority in land and resource use with other important tenures, water catchment being the most significant in the Southern and Western Coalfields. Some natural features are clearly more significant than others, but defining the boundary between 'significant' and 'less significant' or 'not significant' is fraught with problems.

Large and floristically diverse swamps clearly are more significant both ecologically and hydrologically than small patches of banksia thicket, but drawing the line between these extremes has been bedevilled by differences over definitions. High waterfalls are more spectacular and have been required to be protected, but nickpoints that are small, but perhaps above ecologically crucial small pools, have been deemed unworthy of protection. Endangered ecological community status for upland swamps has not in itself been considered sufficiently significant to ensure protection from subsidence damage because the swamps are widespread above coal resources, and full protection would sterilise much coal.

2.2 Groundwater

Approvals have set Trigger Action Response Plans (TARPS). For example, the Dendrobium AEMR, 2012-2013, notes that groundwater inflows are monitored under a TARP approved by the Dam Safety Committee (Figure 3). These define levels of concern, but for our society to answer the question of 'what is acceptable?' requires concern to be translated into action. When does a 'concern' become a response requiring a change to the mining activity?

In this case, only when the inflows lead to a loss of groundwater and/or a possible loss of stored water of more than 1.9ML/day – (40 times the 'normal' value of <0.5ML/day) – is there a requirement to stop mining operations. For lesser inflow and stored water losses, there are advices to the DSC and SCA, more frequent monitoring and review, consideration of Incident Management Team activation etc, but no specific requirement for a change to mining operations. Nor does this TARP consider long-term losses via change to groundwater piezometric conditions; it is directed only at inflows while mining.

2.3 Water quality

So called 'iron springs' are a typical consequence of mining induced subsidence beneath and near watercourses in Sydney's drinking water catchment, arising when water passes over freshly exposed rock faces in fractured and displaced sandstone bedrock. Once initiated, iron springs persist for decades, posing a threat to aquatic ecosystems and to downstream water storage. While they can and do occur as a consequence of movements in the sandstone bedrock arising from natural stress relief impulses, water-rock interactions on the Woronora Plateau have otherwise largely equilibrated over geologic time.

As is suggested in the 2010 BSO PAC Panel report (PAC 2010), mining operations are a likely trigger for the onset, reactivation or aggravation of iron spring activity in the Special Areas of Sydney's drinking water catchment.

The dissolution of carbonate minerals exposed by rock cracking releases metal contaminants, such as iron, manganese, aluminium, barium and strontium, that can exceed the ANZECC 95% protection of aquatic species trigger values. Dissolved ferrous iron colours the water green, and as the dissolved iron is exposed to oxygen, colloidal ferric oxyhrdoxides form and impart a milky opacity to the water. Subsequent precipitation can stain bedrock orange-red for many hundreds of metres downstream (see Figure 4). The mild acidity of rain is sufficient to redissolve and remobilise precipitated metals, moving them further downstream. Natural foaming on the surface of water following rain can carry precipitates downstream and into storage. The Sydney Catchment Authority estimates that between February 2002 to August 2009, 15.4 tonnes of iron and 4.0 tonnes of manganese (Jankowski & Knights 2010

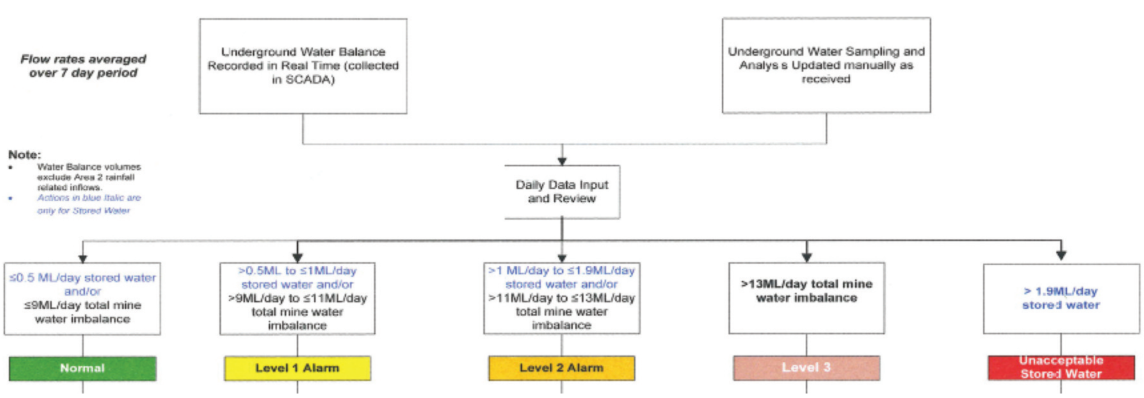

Figure 3 **Trigger Action Response Plan**
From the Avon and Cordeaux Reservoir DSC Notification Area Management Plan (BHP Illawarra Coal AEMR 2012-2013, Figure 3-8)

(b)) were added into the Woronora Reservoir. More will have been added since.

Elevated levels of dissolved iron and manganese encourages the growth of orange-red iron oxidising bacteria on bedrock (see Figure 4) and these bacteria can also cause an oily film on the surface of water. The 2009 Director General's report approving the expansion of the Metropolitan Colliery comments on the potential ecological effects of iron oxidising bacteria based flocs include *'smothering of benthic habitat and biota and reduced light available for aquatic plants. Bacterially-catalysed oxidation of iron also consumes dissolved oxygen from the water column.'*

Figure 4 **Heavy iron oxidising bacteria growth, iron staining and algal growth on the bed of the Waratah Rivulet above Longwall 20 of the Metropolitan Colliery and about 2.5 km upstream from the entrance to Woronora Reservoir**

The photograph was taken on February 13 2014

The 2011 Australian Drinking Water Guidelines recommend a limit of 0.3 mg/l for iron in drinking water and this provides an important benchmark for water quality. Iron doesn't pose a threat to human health but it does degrade the taste and utility of water. Iron is however readily removed from water and, reflecting this, the Sydney Catchment Authority's limit for its supply to the Woronora Filtration Plant is 1.0 mg/l. The operating costs of the Woronora Filtration Plant are not publicly available.

2.4 Swamps

Astonishingly, there is no adequate hydrological balance for any of the upland swamps on the Woronora or Newnes Plateaus.

In recent years, some coal companies have constructed hydrological models but these are based on only a few years' data, estimate the crucial parameter of evapotranspiration from climatic variables, not direct lysimeter measurement, and do not adequately distinguish either contributions to baseflow from average flows out of the swamps or the changes due to mining activities. Thus, the quantitative impact of mining on the swamp hydrology, and the resultant impact on catchment yield, is a matter of dispute. What is now obvious is the loss of water from swamp sediments that persists over years and through both drought and high rainfall conditions.

The approval for Area 3B of BHP Biliton's Dendrobium mine requires:

(i) For seven large swamps: negligible erosion, minor changes in swamp size and ecosystem functionality, no significant change to species composition and distribution, and maintenance or repair of the bedrock base of permanent pools or controlling rockbars.

(ii) For another six swamps: damage to be not 'beyond prediction'!

The terms 'negligible', 'minor', 'significant; have been defined for some impacts, for example, by specifying length and width of bedrock cracks. However, there are no such straightforward standards set for important consequences such as loss of ecosystem functionality or change in species composition and distribution, let alone for cracking that is concealed by the blanket of swamp sediments.

The swamp impact management plan does not acknowledge that loss of shallow groundwater implies loss of ecosystem functionality, so many years of monitoring is required to establish the occurrence/ severity of this loss. It is hard to see how a useful Corrective Management Action (CMA) is possible, as there is no established and tested remediation strategy for rehabilitation of a subsidence-damaged swamp. There is no evidence for self-sealing of cracked bedrock in a swamp's base; injection grouting under swamp sediments is likely to do more damage than good even if the cracks could be accurately located; and coir logs and water spreading techniques are only useful to control surface water movement, not drainage to the underlying bedrock. For practical purposes, therefore, approval to undermine a swamp implies that damage to the swamps is 'acceptable'. This was stated explicitly by the Director-General in his approval of Dendrobium Area 3B:

> *'Notwithstanding, the proposed mine plan is likely to result in damage to up to twelve coastal upland swamps arising from mine subsidence.'*

The first longwall passed under four swamps mapped as 'swamps of special significance' by the NSW Office of Environment and Heritage draft guidelines. The result was an immediate loss of water from the swamp sediments and drying up of the stream exiting from at least one of them, as monitored under an Environmental Trust Grant (Figure 5, from Krogh 2013).

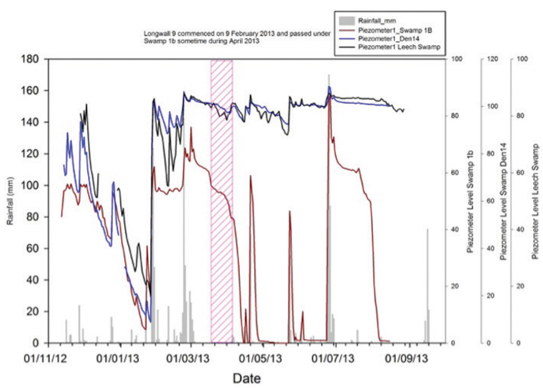

Figure 5 **Piezometer levels for Swamp 1B above Dendrobium LW9 (red line), with comparative data from two nearby swamps unaffected by mining (blue and black lines) (from Krogh 2013)**

3. Criteria that could be established and some that are established

3.1 Groundwater systems

Groundwater systems are one aspect for which criteria have been set. The NSW Aquifer Interference Policy was released in September 2012 and applies across the State.

It explains the water licensing and impact assessment processes for aquifer interference activities under the Water Management Act 2000 and other relevant legislation. Significant negotiations occurred between officers of the NSW Office of Water (NOW), mining companies and those of us concerned with Australia's limited water resources during development of the policy. We consider that the work done by the NOW was excellent and the final version of the policy is clear and quantitative. How it will work out in practice only time will tell.

One of the important facets of the policy relates to the use of the term 'aquifer', one that is so often misunderstood and misused. The policy notes that the term 'aquifer' is commonly understood to mean a groundwater system that can yield useful volumes of groundwater. The policy itself is based on the following premise:

> ***For the purposes of the Aquifer Interference Policy the term 'aquifer' has the same meaning as 'groundwater system' and includes low yielding and saline systems.***

A particularly valuable part of the work done by NOW is in the form of the Factsheet Series, which comprises six explanation documents on the NSW government website (www.water.nsw.gov.au – Quick links: Aquifer interference). These documents provide clear explanations of the key facets of the policy.

There are three parts to the policy:

(i) all water taken must be properly accounted for;

(ii) the activity must address minimal impact considerations for impacts on water table, water pressure and water quality;

(iii) planning for measures in the event that the actual impacts are greater than predicted, including making sure that there is sufficient monitoring in place.

A key part of the policy is that quantitative thresholds for minimal impact considerations have been developed for each groundwater source in NSW. The thresholds relate to impacts on:

(i) groundwater table – the actual height of groundwater in parts of groundwater sources that are not confined by overlying rocks or sediments;

(ii) groundwater pressures – the pressure of the groundwater in parts of groundwater sources that are confined by overlying rocks or sediments and, therefore, under pressure. The change in water pressure is the height corresponding to the height that water would rise to if a bore was connected into that part of the groundwater system; and

(iii) groundwater and surface water quality – whether a change to any quality parameter would change the water quality enough to potentially impact on current and future uses. The assessment also considers whether the activity will increase the salinity of groundwater or any highly connected surface water.

The Minimal Impacts are detailed in tables in the full policy but are well illustrated in the fact sheets for different groundwater systems. For consideration of underground coal mining impacts, porous and fractured rock groundwater systems are the important feature, and the Minimal Impacts are illustrated by NOW as in Figures 6 and 7, below.

We think that the policy as it currently stands is a reasonable compromise between protection of valuable water resources, the environment that depends on those sources, and appropriate development of mining activities. However, the real test will come in the next decade as projects are approved, developed and operated under this policy.

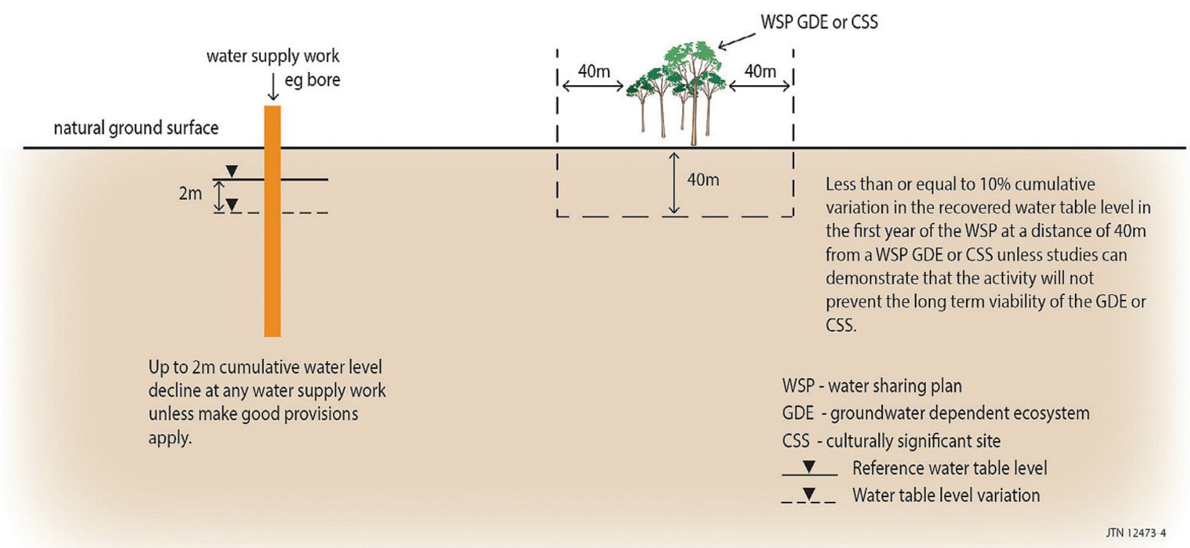

Figure 6 **Maximum impacts considered acceptable in respect of the water table**

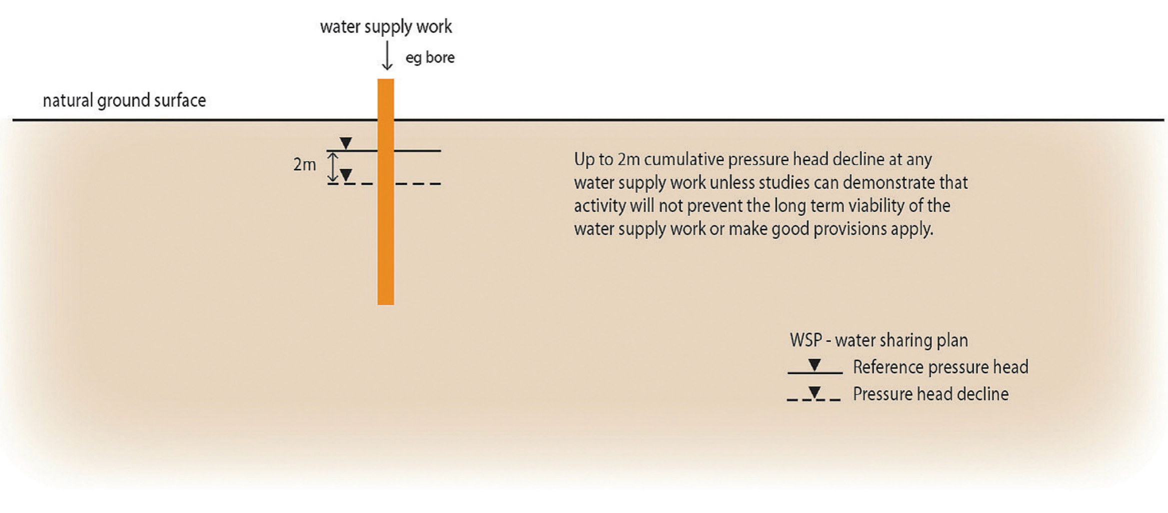

Figure 7 **Maximum impacts acceptable for groundwater pressures (excluding the Great Artesian Basin).**

3.2 Upland swamps

How, if at all, do we decide which swamps are 'significant' and worthy of protection, and which are less valuable and not worthy of protection? This dilemma is accentuated by the absence of rehabilitation / remediation options: protection relies solely on a mine plan that prevents subsidence impacts likely to crack the bedrock underlying a swamp (see Figure 8).

Figure 8 Within-prediction cracking of a now-dry rock bar downstream of an undermined swamp

Size is an obvious criterion. Large swamps store useful volumes of water which then drain slowly during dry periods and maintain environmental flows downstream. The loss of water from pools below damaged swamps makes this abundantly clear (as, for example, on Waratah Rivulet below Flat Rock Swamp and on its tributary below Swamp 21 above Metropolitan mine near Helensburgh).

Large swamps are usually diverse floristically, with several or all of the swamp vegetation types (banksia thicket, sedgeland, restioid and cyperiod heath and tea-tree thicket) represented. Their pools, and their deep and permanently damp sediments are important ecological niches for stygofauna such as yabbies and the endangered giant dragonfly, as well as a number of endangered frogs. However, size of individual swamps alone is not an adequate measure. Many swamps are closely adjacent, separated only by fringing eucalypt woodland and occupying 1st-order valleys, which together support flow into the larger valleys downstream. Logically, hydrologically and ecologically these should not be seen as discrete swamps but as a cluster, and such clusters should be afforded high significance.

For upland swamps, the criteria of acceptable impact must be loss of water from the sediments, not an undefined 'change of ecosystem functionality' over an unspecified time.

Because remediation of damaged swamps is near-impossible we consider that the swamp systems of the Sydney Basin should be categorised in a way similar to the following:

Category 1

(i) individual swamps of > 3ha that are diverse floristically, and provide important ecological environments;

(ii) listed as Endangered Ecological Communities;

(iii) significant hydrologically i.e. occupying more than a particular percentage of the catchment of a perhaps-2nd order stream, whether as an individual swamp or as a number of swamps in smaller sub-catchments.

Category 2

(i) strings of smaller swamps aggregating > 3ha; otherwise as per Category 1.

Category 3

(i) swamps < 3ha in area.

We suggest that underground mining at a depth up to nominally 500m should not occur beneath swamps in Category 1 and 2.

3.3 Water Quality in Surface Waters

Water is a key trigger issue for public disquiet about the impacts of mining and the consideration of what constitutes an acceptable balance between impact and benefit. The importance of water, both quantity and quality, leaves little room for compromise. Coal mining beneath Sydney's drinking water catchment has long been controversial and the evolving tension is captured in the 2008 report of the Southern Coalfield Inquiry (Dept. Planning 2008), the 2009 Planning Assessment Commission (PAC) report for the expansion of the Metropolitan Colliery (PAC 2009) and the 2010 PAC report for the Bulli Seam Operations (BSO) project (PAC 2010).

Presented as a case study by the NSW Parliamentary Library (Smith 2009), the once pristine Waratah Rivulet is a well-known and well-studied example of a significant watercourse adversely impacted by longwall mining (Jankowski & Knights 2010 (a and b), TEC 2007). The river provides a point of reference for mining impacts elsewhere in Sydney's drinking water catchment: the impacts suffered by the Waratah Rivulet are reflective of impacts above and around other mines operating in the Special Areas (Dept. Planning 2008, PAC 2009, PAC 2010, Krogh 2007, McNally & Evans 2007, NSW Scientific Comm. 2005).

The Waratah Rivulet was undermined and badly damaged by subsidence arising from a set of panels approximately aligned with the river and extracted between 2003 and 2006; these longwalls were a subset of a larger series mined between 1995 and 2010. Following approval in 2009 to expand the mine extraction of a new set of panels, contiguous but perpendicular to those previously mined, commenced in May 2010 (see Figure 9).

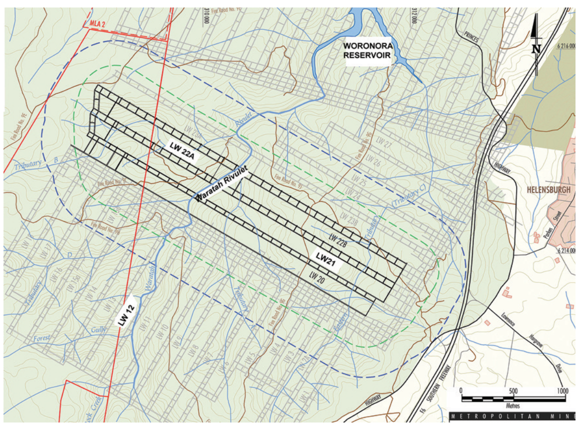

Figure 9 **Map (Peabody 2010) showing the previously extracted (southern), recently extracted (bold lines) and planned (northern) longwalls of the Metropolitan Colliery, located in the Schedule 1 Woronora Special Area.**

Reflecting community and agency concerns, the *project approval requires 'Negligible reduction to the quality of water resources reaching the Woronora Reservoir'*, where negligible is defined as *'small and unimportant, such as to be not worth considering'*. Commendably, the water management plan (WMP) for the first stage of the expansion of the Metropolitan Colliery introduced, possibly for the first time in the Southern Coalfield, a quantifiable performance indicator intended to benchmark changes to water quality.

The water management plan's water quality performance indicator is triggered if any water quality parameter should exceed the baseline period mean concentration plus two standard deviations for two consecutive months.

A standard deviation is an easily calculated statistical measure of how much a given data set varies from its average or mean value. Approximately 68% of a data set that has a statistically 'normal' distribution (see Figure 10) will be one standard deviation away from the mean concentration. Two standard deviations capture 95.4% of data and three standard deviations captures 99.7% of the data. In principle then, the water quality performance indicator seems reasonable and sufficiently straightforward that most would recognise that it gauges the baseline water quality, captures its variability and could provide a reasonable benchmark for assessing changes to water quality arising from the new mining. As is all too often the case, however, the devil is in the detail.

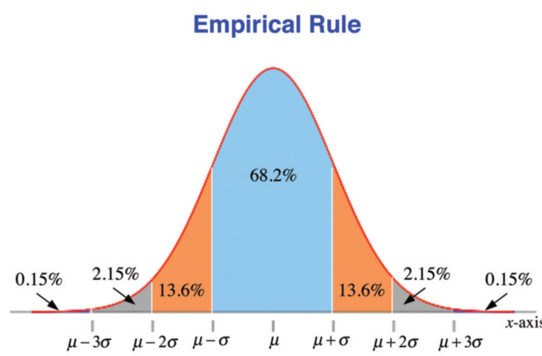

Figure 10 **Depiction of a normal distribution, in which 68.2%, 95.4% and 99.7% of data are within one, two and three standard deviations (σ) respectively of the mean (μ).**

The WMP performance indicator for water quality is muddied by a footnote that states 'Log transformations (i.e. base 10 logs of the water quality concentrations) may be used to calculate the arithmetic means and standard deviations. Metal concentrations in water quality are measured as a positive value and therefore have a positively skewed distribution. Log transformations can be used to standardise the variance of a sample' (Bland, 2000). The footnote, which is unclear and in some respects misleading, is not elaborated upon or discussed in the main text of the water management plan. Given the significance of the transformation, it should have been[1].

In the case of iron concentrations at the site used to assess the quality of water entering the Woronora Reservoir from the Waratah Rivulet the transformation has the opposite of the intended outcome of the transformation; the data distribution is further removed from being normal (Figures 11 and 12). That is, the application of a logarithmic transformation is not appropriate for the iron concentration data; the log transformations does not standardise the variance of the data.

Deviation from normality erodes the viability of using the standard deviation to characterise a data set. While the original, untransformed, iron concentration data represented in Figure 11 is closer to being normal than is the transformed data, it also nonetheless deviates from normality. While the WMP is to be commended in including a quantifiable performance measure for water quality, it fails to test the assumptions used in formulating that measure.

A relatively simple alternative to the use of the standard deviation to characterise the data and set a performance benchmark when data deviate from being normal would be to use the 'interquartile range' – the range of values between the first and third quartile. This makes no assumptions about the nature of the data distribution. However the benchmark is defined, it must be credible and 'fit for purpose'.

The benchmark for iron concentrations entering the Woronora Reservoir from the Waratah Rivulet obtained using the flawed method of the WMP for the expansion of the Metropolitan Colliery is 0.54 mg/l. This seemingly small number is given sharper context when compared to the Australian Drinking Water Guidelines recommendation of 0.3 mg/l and the 0.18 mg/l average and 0.10 to 0.23 mg/l interquartile range of the baseline

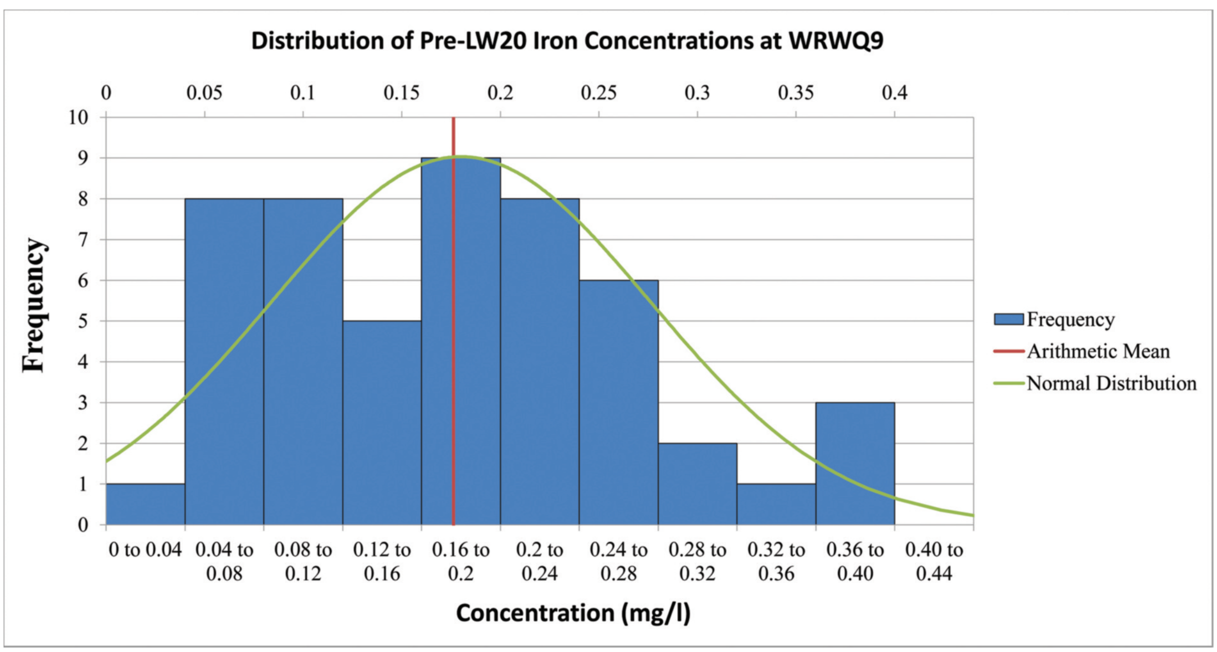

Figure 11 **Histogram showing the distribution of baseline period iron concentrations at the site used to gauge the quality of water entering the Woronora Reservoir**
A normal distribution with the same mean and standard deviation is shown for reference; the data distribution deviates from that of the normal distribution (see Figure 10)

[1] Most significantly, the management plan fails to make a sufficient case for the application of a logarithmic transformation to the metal concentration data; in fact it fails to make any case at all. At the time of the preparation of the WMP for the commencement of the expansion project, there was sufficient data available to assess the nature of the baseline data distribution and determine whether or not the application of a transformation would beneficially result in a better approximation to a normal distribution. The management plan did not however include such an assessment.

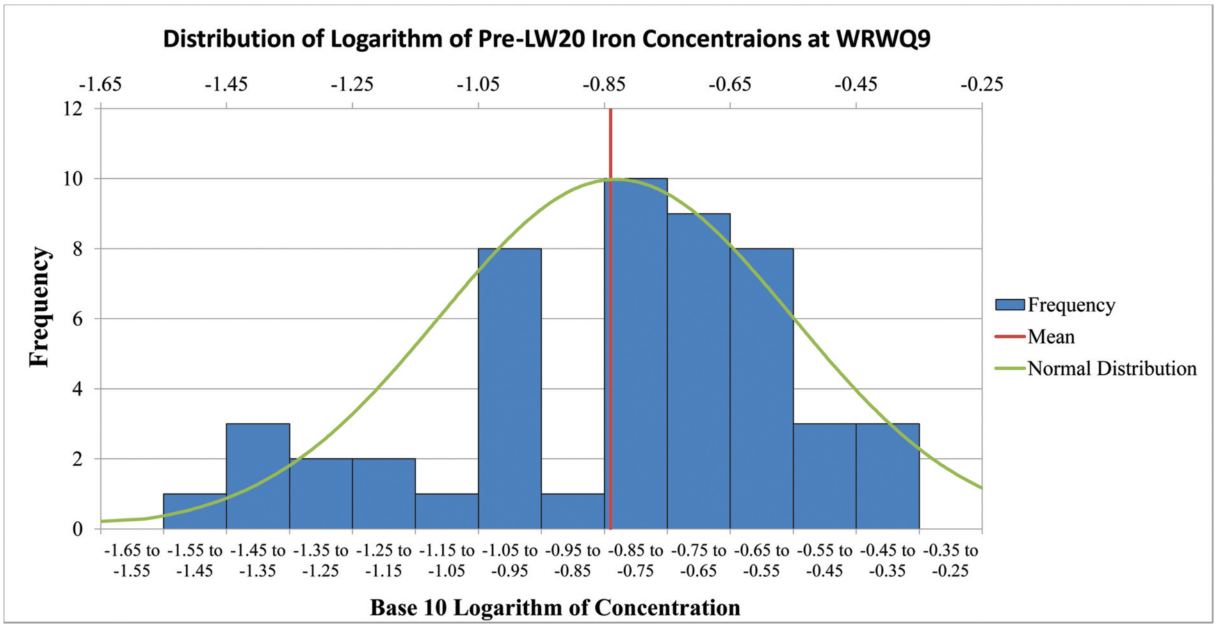

Figure 12 **Histogram showing the distribution of the logarithmic transformation of the baseline period iron concentrations at the site used to gauge the quality of water entering the Woronora Reservoir**
A normal distribution with the same mean and standard deviation is shown for reference; the data distribution deviates further from that of the normal distribtion (see Figure 10) than does the original data (see Figure 11).

period concentrations. The 0.54 mg/l iron concentration benchmark would not be regarded by most as being fit for purpose, given the requirement of negligible reduction in water quality.

There are important lessons here. Assumptions made in setting performance benchmarks should be clearly explained, justified and, to the extent that it is possible, tested for credibility. Community consultation provides an opportunity to develop mutually acceptable criteria, resulting in improved operational performance and establishing and maintaining trust. Management plans are rarely made available for public comment, thereby denying opportunity for valuable and mutually beneficial community input consistent with the expectations of having and retaining a social licence (Seeger 2011) for mining.

3.4 Cliffs

For the purpose of this discussion cliff lines are defined as near vertical stepped rock exposures of height greater than 6m, within an average slope angle of 45 degrees or greater. Typically, in the Blue Mountains area through to Ulan, and in the Southern Coalfields, cliff lines of particular aesthetic value comprise single, or multiple stepped, exposures higher than 20m and up to about 200m.

Experiences at several mines[2] and analytical calculations (Pells 1991) have shown that the probability of induced collapses of near vertical cliff, in strata such as the horizontally bedded Hawkesbury, Bulgo and Burra Moko Head sandstones is High[3] where near total extraction occurs beneath and/or immediately in front of cliff lines. Conversely, the probability of induced collapses is Very Low where near total extraction is further behind cliff line crests than the depth of mining (i.e. an angle of 45^o from crest to the edge of extraction.

[2] Katoomba Colliery, Newnes Torbanite Mine, Baal Bone Colliery, Angus Place Colliery; all in the Blue Mountains, and Dombarton, Tower and Nattai North collieries; in the Southern Coalfields.

[3] High Probability is here suggested as being a probability of occurrence of greater than 1 in 20 for cliffs of height >10m; i.e. if there were 20 similar such discrete cliffs in an area undermined by longwalls at least one would collapse, or in a 200m long cliff line, at least one ~10m length would collapse.

Some attempts have been made to set 'social value' to cliff lines (ACARP, 2002) as used in the Xstrata Environmental Impact Assessment for the West Wallsend longwalls beneath Sugarloaf State Conservation Area. The ACARP (2002) system as reproduced in Table 1 involves calculating a proportional score for a cliff line by multiplying a 'score for each factor' by a 'weighting' and then dividing the result by the maximum possible weighted-score of 696. Thus a cliff line that ticks all the boxes in the last column of Table 1 ends up with a 'proportional score' of 1.0, and is classified as Extremely High, according to Table 2.

Proportion of maximum score	Ranking	Classification
0 - 0.1	1	insignificant
0.1 - 0.2	2	very low
0.2 - 0.3	3	low
0.3 - 0.4	4	moderate
0.4 - 0.5	5	high
0.5 - 0.6	6	very high
> 0.6	7	extremely high

Table 2

It is our view that the ACARP system is flawed to the point of being meaningless because it combines aesthetic quality with degree of public exposure. In particular:

(i) The two dominant factors (35% of rating system) are unquantifiable aesthetics[4] and the presence of dwellings near the base of a cliff line, which have nothing to do with the intrinsic value of a cliff line.

(ii) Significant importance is attached to whether a cliff line is easily seen by the public – a bizarre concept that, by analogy, would suggest that the Terracotta Warriors of China only gained value when they were exposed for people to see and prior to that could have been destroyed with impunity.

(iii) The system incorporates highly subjective assessments of cliff types and shapes, as if these are separate to aesthetics.

The significance of pagoda landforms was a major point of discussion in the Coalpac Consolidation project assessment. In rejecting the proposal, the Director-General commented:

> *'The conservation values of the site as a whole are significant, and that the project (in its current form) would essentially destroy these values, and significantly compromise the conservation significance of surrounding areas. The Department considers these impacts to be unacceptable and cannot be mitigated.'*

We consider that a simple system is appropriate based on the principle that the following characteristics make cliff lines sacrosanct, whether seen or hidden:

(i) being an intrinsic part of natural landscape (eg the pagoda structures of the Newnes to Baal Bone area, and the cliffs along the Nepean, Bulgo, Grose, Colo and Burragorang valleys); and/or

(ii) particular features of beauty and ecology (some examples are The Drip along the Goulburn River near Ulan, and the cliffs along the canyons in the Blue Mountains); and/or

(iii) overhangs and caves having a likelihood of association with Aboriginal history.

Because classification of the above cases is so subjective, we think that no pillar recovery or longwall extraction, within a depth of nominally 500m, other than mine access entries, should occur in areas defined by 45^{o} in front of the toe line, to 45^{o} behind the crest line, for at least the following:

(i) cliff lines greater than 50m high;

(ii) any cliff lines that include overhang caves that may have Aboriginal significance;

(iii) any cliff lines that include hanging swamps or similar ecological and groundwater features.

This recommendation in effect covers all but the first column in Table 1.

Where mining is proposed at depths of greater than 500m, specific numerical analyses would have to be undertaken as a basis for quantitative risk assessment – noting that remedial measures are impossible.

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[4] One person's 'spectacular' is another person's 'pleasant'.

Score for each factor	0	1	2	4	6	Weighting
Overall height of talus, cliff face, and crest slope.	< 50m	50m to 75m	75m to 100m	> 100m	> 150m	**2**
Cliff face height	< 20m	20m to 50m	50m to 75m	75m to 100m	> 100m	**5**
Talus slope height	< 20m	20m to 50m	50m to 75m	75m	> 100m	**1**
Cliff face length, or width	< cliff height	> cliff height	> 2 x cliff height	> 5 x cliff height	> 10 x cliff height	**4**
Cliff face angle	< 70o	> 70o	> 80o	> 90o	> 100o	**4**
Talus slope angle of repose	< 15o 1 in 3.73	> 15o 1 in 3.73	> 30o 1 in 1.73	> 40o 1 in 1.2	> 45o 1 in 1	**1**
Vegetation cover on cliff areas	dense vegetation and trees on talus and cliff	dense vegetation on talus and sparse vegetation on cliff	dense vegetation and trees on talus, none on cliff	sparse vegetation and trees on talus, none on cliff	no vegetation or trees on talus or cliffs	**2**
Degree of undercutting or weathering	clean sheer rock face	sheer rock face with small overhangs up to 1m	face with honeycomb weathering and small overhangs up to 2m	delicate honeycomb face or large overhangs i.e. 2m to 4m	delicate honeycomb face or large overhangs > 4m	**5**
Extent of horizontal jointing on cliff face	clean rock face no joints	minimal jointing > 20m	moderately jointed 10m to 20m	heavily jointed < 10m	Severely jointed < 5m	**5**
Extent of vertical jointing on cliff face	no continuous joints	joints continuing over several strata layers	continuously jointed over full height of cliff	several continuous joint systems	continuous open joints or fissures	**3**
In situ horizontal stress at seam level	< 10 MPa	10 to 20 MPa	20 to 30 MPa	30 to 40 MPa	> 40 MPa	**5**
Type of rock strata – rock strength	UCS >100 MPa	UCS > 75 < 100 MPa	UCS > 50 < 75 MPa	UCS > 30 < 50 MPa	UCS < 30 MPa	**5**
Location of cliff in relation to watercourses and valleys	not related	related to small creeks and minor tributaries	related to bluffs lining small valleys	part of major cliff lines lining valleys with talus	part of major cliff lines in gorges or escarpments	**2**
Location of cliff in relation to geological anomalies	not related	related to small faults & dykes < 500 mm	related to continuous vertical jointing	related to major faults & dykes > 500 mm	related to major thrust faults > 500 mm	**2**
Degree of exposure to ongoing weathering agents	not exposed to winds or creeks or streams	partly sheltered from winds and creeks or streams	exposed to winds and to small creeks or streams	exposed to wind action and next to major river	exposed to strong wind action and next to major river	**2**
Presence of water flows at base of slope	no stream or creek	stream or creek with gradient of less than 1 in 100	stream or creek with gradient of more than 1 in 100	river or creek with gradient of more than 1 in 75	river or creek with gradient > 1 in 50	**3**
Presence of loose & unstable blocks on cliff	few unlikely to fall	few could possibly fall	many could possibly fall	few likely to fall	many likely to fall	**5**
Loose and unstable blocks on talus	few unlikely to fall	few could possibly fall	many could possibly fall	few likely to fall	many likely to fall	**2**
Presence of natural cracks in cliff crest	none	one	two or three	several	many	**5**
Orientation of natural cracks relative to cliff line	no cracks or 90o to 60o	60o to 40o	40o to 20o	10o to 20o	< 10o	**5**

Table 1

4. Conclusions and questions

In order to for a mining operation to gain acceptance in the wider community, consistent with the increasingly widely recognised concept of a social licence (Seeger 2011), its environmental performance criteria must be impeccably credible and transparently defined in such a way that they will be viewed and accepted as being credible by that community. Invoking the mystique of the professional, and urging the concerned or curious members of the community to 'trust the experts' constitutes a failure of social responsibility likely to inspire the suspicion that 'smoke and mirrors' are at play and intended to deflect scrutiny and/or circumvent project approval requirements.

In the same way that we accept rare and endangered species and communities of flora and fauna as meriting greater weight in conservation than ubiquitous and common ones, so we recognise some landforms as more spectacular, more ecologically valuable, more restricted in distribution – more significant – than others. We give greater weight to maintaining flow and quality in some streams more than in others. Streams in water catchments, or flowing through, or into, environmentally sensitive areas (such as national parks and/or urban areas), or occupying high order valleys or gorges, have all been recognised in recent years as deserving special consideration.

The NSW Planning Assessment Commission (PAC), in its assessments of both the Metropolitan Expansion and the Bulli Seam Operations projects, spent some time on this matter with respect to cliffs, swamps, streams and Aboriginal heritage sites. The PAC specified criteria to define features of special significance and recommended that 'negligible' damage be permitted to them. The PAC (PAC July 2010) noted:

- some key information for assessment of special significance of some significant natural features was not available;
- levels of acceptable impacts on some significant features had changed over time;
- there were problems with a proponent defining what was of 'special significance'.

While legislation is reasonably adept at protecting flora and fauna, it is less developed for the abiotic environment. However, legislation defining criteria for significance of landforms does exist and is familiar within the World Heritage system. There is always judgement needed, but inter-disciplinary expert opinion can provide a sound basis for deciding whether or not a feature has a high level of significance.

We argue that it is feasible and necessary for analogous criteria to be developed to identify and then protect significant cliffs, streams, swamps and groundwater/surface water resources. It is never possible with natural systems to fit them neatly into discrete and unambiguous and undisputed boxes, but it is both possible to classify them into consistent groupings of genuine relevance and interpretive value. The criteria will include those already-established for biodiversity components but also others for hydrology (both surface and groundwater) and landforms.

A key question is how our understanding of significance should be applied. Are some features of such high or special significance that they are 'ring-fenced', in a way analogous to the exclusion of coal mining from a zone around wineries and horse studs in the Hunter Valley or CSG extraction from close to urban areas? Or must all features be dealt with for each major development and their protection argued for case-by-case? If so, how are the cumulative impacts taken into account in a way which is fair to developments that come later in the mining area than early ones? Or are anticipated cumulative impacts factored in early in the regional planning process?

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