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30 July 2007

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Dear Mr Downes

The NSW Minerals Council (NSWMC) welcomes the opportunity to make a submission to the Independent Expert Panel into Underground Mining in the Southern Coalfield (the Panel). NSWMC has supported the Panel process from the outset, recognising that there is community concern about the impacts of longwall mining on natural features. The Panel provides an opportunity for experts to provide a science based assessment of the potential impacts, risk management, monitoring and the quality of remediation strategies.

The attached submission presents the views of the NSW minerals industry and has been developed in close consultation with collieries operating in the Southern Coalfield. The submission provides a 'helicopter view' of the mining industry in the Southern Coalfield including: key regional and State economic and social information for the industry; the subsidence prediction, assessment and management techniques used by the industry; and some of the regulatory frameworks within which the industry operates.

The submission also discusses decision-making frameworks that can be used to manage the various environmental risks involved with underground mining – concepts which can be applied to mining more generally. It is apparent from this discussion that there are substantial links between the Panel and the Department of Primary Industries' Subsidence Management Plan Review which is currently underway. NSWMC's submissions to these two processes are related, and the outcomes from each process should be developed in conjunction with one another.

A number of supporting documents are attached which provide further detail on the various issues raised in the submission, and can be referred to by the Panel when required. NSWMC is, of course, happy to be of any assistance to the Panel throughout the process. We look forward to future discussions with Government about the potential implementation of the Panel's recommendations.

For further information, please contact Georgina Beattie, Deputy-Director Environment & Community, on (02) 8202 7205 or gbeattie@nswmin.com.au.

Yours sincerely

Dr Nikki B. Williams
CHIEF EXECUTIVE OFFICER

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NSW Minerals Council

Submission to the Independent Expert Panel into Underground Mining in the Southern Coalfield

July 2007

Executive Summary

NSW is in the unique position of possessing vast reserves of high quality, economically recoverable coal. The State's economy has developed using affordable, reliable electricity generated by coal-fired power stations and steel produced with coking coal from the State's Southern Coalfield. In export markets, there is high demand for NSW's thermal and metallurgical coals as a result of growing electricity and construction demands internationally, coupled with NSW's reputation as a high quality producer, with reliable supply chains, using world class infrastructure.

There is no denying that the coal industry makes a significant contribution to both the economic and social prosperity of NSW residents, and that mining companies play active, positive roles in the local communities in which they operate. The mining industry in NSW's Southern Coalfield is no exception, having had a long history in the region and being uniquely placed as the only source of high quality coking coal in the State. Mining in the Southern Coalfield has created significant benefits for the local community in terms of employment, infrastructure and other community contributions, with flow on benefits extending throughout the State.

There are many complex site specific factors that can affect the extent and magnitude of impacts to natural features as a result of underground mining. Impact assessments and development of impact minimisation measures can only be completed successfully on a case by case basis. Mining proposals should be assessed using a clear, consistent and comprehensive analysis of the trade-off between all environmental, social and economic factors. This allows the Government to make decisions based on the net benefit to society, including the acceptability of impacts.

In preparing this submission, NSWMC has identified a number of key issues for consideration by the Panel. These are summarised below.

Assessment of underground mining proposals should consider environmental, economic and social factors to determine acceptable levels of impacts

- Subsidence from underground mining will have some environmental effects – as do most kinds of development. The question that needs to be answered is one of the acceptability of impacts.
- Mining induced ground movements at a point on the surface do not necessarily result in adverse environmental impacts at that point.
- The Government must make decisions on the acceptability of impacts by assessing a project's net benefit or cost to society by taking into account all economic, social and environmental factors.
- The current Subsidence Management Plan (SMP) process could be improved to account for economic benefit versus environmental impacts on significant features.

Despite claims to the contrary, the science of subsidence prediction is robust

- Observed levels of subsidence are within those predicted in the vast majority of cases.
- Significant advances in subsidence prediction and management have occurred in recent years.
- Historically, unexpected impacts have occurred as a result of subsidence. In these cases no impact assessments were actually completed prior to mining because of the regulatory and social framework that operated at the time.
- Subsidence models provide conservative predictions of subsidence. This conservatism is an inbuilt precaution that accounts for any uncertainty around subsidence movements.
- Many of the impacts that have generated community concern were predicted to occur and were approved by Government.

Each mining proposal should be assessed on its own merits

- Geology, subsidence behaviour and the nature of impacts and the receiving environment all vary both within and between mining regions. The economic value of coal reserves also varies between different areas.
- Assessment processes are in place to ensure effective assessment of individual projects based on science. This case by case approach to assessment should continue to ensure informed decision making.

The environmental impacts of mining need to be considered in a regional context

- Environmental impacts may be insignificant in a regional context. The impacts of mining may be localized or temporary, and not as relevant when considered in the context of other land uses in the region.
- Impacts from mining in the Southern Coalfield should be considered within the context of the whole sandstone plateau in the Illawarra region.

Mandated setback zones are not appropriate

- A mandated setback distance is illogical. The extent and magnitude of subsidence related movements are related to many factors including depths of cover, seam thicknesses, and longwall and pillar widths.
- Optimised decisions around impacts and mitigation can only be made with the benefit of a location specific knowledge and assessment. The use of different types of measures and the acceptability of some impacts needs to be considered to provide the greatest net benefit to society.
- Mandated setback zones are as political tool, rather than one based on science.

Mitigation and remediation of subsidence impacts can be successfully achieved through a number of methods

- Mitigation of impacts through mine planning and design, and active and natural remediation have all successfully reduced the impacts on natural features in the Southern Coalfield.

NSWMC makes the following recommendations to the Panel:

- Support for the general SMP process and consideration of environmental restrictions on a case by case basis.
- Recognition by the Panel that the current implicit goal of no or minimal environmental damage of underground mining is unlikely to be economically efficient and it is the Governments responsibility to make decisions that are best for the community as a whole rather than for specific vested interest groups.
- Recognition by the Panel that proposals for set restrictions on underground mining in relation to natural features are unlikely to be economically efficient and will impose unnecessary opportunity costs on society.
- Recognition by the Panel that the current risk management framework embedded in SMPs has been effective in predicting subsidence impacts and that interest group concerns largely revolve around their own view of the acceptability of predicted impacts rather than the acceptability from a whole of community perspective.
- Understanding by the Panel and community that without recognition of the above, industry may continue to be pressured into making sub-optimal decisions to sterilise large quantities of coal resource and ultimately reduce investment in the Southern Coalfield.
- Extension of the SMP process to explicitly consider the economic trade-off of different levels of environmental restrictions in SMPs, including no restriction, on a case by case basis. This economic trade-off should be the primary consideration of government in approving SMPs. In this respect, early consultation with government about the economic trade-off of different mine plans is important to avoid the business costs associated with lengthy approval times.
- Support from Government in sponsoring non-market economic valuation studies of different environmental outcomes to facilitate economic trade-off analysis.
- Improved communication to interest groups and the public of the of the expected, and Government accepted, subsidence impacts of underground mining and the fact that approved mining is expected to have some environmental impacts.

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1 - Introduction

The NSW Minerals Council (NSWMC) is a major stakeholder in many of the environmental, social, regulatory and economic issues critical to the sustainable development of New South Wales. The industry has a demonstrable record of good environmental management and continuous improvement, in no small part due to co-operative, consultative and constructive approaches towards ensuring balanced development outcomes. NSWMC seeks to ensure that any environmental regulation and policy meets the basic criteria of effectiveness, efficiency and fairness.

NSWMC is the peak body representing mineral exploration companies and the producers of coal, minerals and extractive materials in this State. The NSW minerals industry has an annual production value of more than $11 billion. Mining and minerals production employs over 47,000 people directly in NSW, mainly in rural and regional areas, and provides indirect employment, estimated to be in the order of a further 200,000 people, in a large number of support industries ranging from heavy engineering and equipment manufacturing to the provision of mine supplies, consumable items and specialised advisory, design and management services.

The industry contributes over $1.5 billion per year to government revenues, with coal continuing to be the State's largest export earner at over $8 billion per year. The export of Australian mining equipment, technology and services is also significant and is estimated at over $5 billion per year.

NSWMC supports the Independent Expert Panel into Underground Mining in the Southern Coalfield (the Panel), recognising the genuine community concern regarding subsidence-related impacts on natural features. The Panel provides an opportunity for the experts to provide a strategic, science-based assessment of the potential impacts, risk management, monitoring and remediation strategies in relation to significant natural features and their associated values.

There have been previous investigations into underground mining that are relevant to this review. The Stored Waters Inquiry of 1976 by Justice Reynolds (the Reynolds Inquiry) found that in "the public interest, the relevant mining should be permitted because the valuable resource of coal reserves may be mined without endangering the security of the stored waters if the mining is carried out with proper safeguards." Another inquiry, the Dendrobium Inquiry of 2001 "raised the bar" with respect to the requisite degree of data acquisition in advance of mining, and ongoing monitoring of impacts. Since then, the mining industry has continued to improve its approach to subsidence prediction, impact assessment and management. Several research projects have been undertaken through the industry's Australian Coal Association Research Program (ACARP) which have again redefined best practice in this area. The Subsidence Management Plan (SMP) process was introduced by the NSW Government in 2004. This has also improved rigour and transparency in the management of subsidence.

Despite these improvements, underground mining has and will continue to result in some environmental impacts. This submission seeks to outline the science behind subsidence management, the balance required between economic, social and environmental aspects of underground mining and the risk management framework that is adopted by the industry as part of its decision making process on this issue. Ultimately, it is the government that must determine whether these environmental impacts are acceptable in light of the economic and social benefits of mining. NSWMC believes that the planning process in NSW is designed to effectively balance these aspects in light of the principles of Ecologically Sustainable Development, and that the industry embraces such an approach.

Further details on issues raised in this submission can be found in the attached reports by Mine Subsidence Engineering Consultants (MSEC), Biosis Research, Dr Noel Merrick and Gillespie Economics.

2 - Background to mining in the Southern Coalfield

NSW coal production comes predominantly from 5 coal fields: Hunter; Newcastle; Southern; Western; and Gunnedah. The Southern Coalfield extends south and southwest of Sydney to Bargo and Berrima. There are currently 9 mines operating in the Southern Coalfield. Appendix 1 shows the approximate extent of current and historic underground mining in the region.

The primary method of coal extraction in the Southern Coalfield is longwall mining. Longwall mining is a method of underground coal mining whereby blocks of coal, known as ‘panels’, are extracted from a coal seam by a shearer moving along the face of the panel. As mining progresses along the length of the panel, the overlying strata collapse behind the advancing longwall face.

Most collieries in the Southern Coalfield extract coal from the Bulli and Wongawilli Seams, and some extraction occurs in the Balgownie Seam. The coal seams generally deepen from south to north, with mining at collieries to the south extracting coal from around 100 metres below the surface, while in the north, mining is more than 500 metres below the surface. As the collieries progress further north, mining depths are likely to exceed 700 metres. The recoverable thickness of the coal seams varies between 1 and 4 metres, although most extraction is generally between 2 and 3 metres. Longwall panels in the Southern Coalfield are typically between 150 and 300 metres wide and extend for some kilometres in length.

There are many other land uses within the Southern Coalfield other than coal mining. Within Sydney’s drinking water catchment, mining comprises 0.2% of land use. This is low when compared to other land uses such as grazing and improved pasture (37.2%) and urban and rural residential (3.4%) (SCA 2005). Each land use has impacts on the environment, such as:

- Erosion and water quality issues resulting from free ranging stock (Biosis Research 2007)
- Management of water storage and river flows in the water supply catchments, resulting in altered flow regimes and increased barriers to fish passage (Biosis Research 2007)
- Discharge from sewage and septic systems, urban runoff etc leading to water quality issues (Biosis Research 2007).

The relative impacts of mining need to be considered in this context. It is also important to consider impacts from mining in the context of the whole region.

3 - Social and economic significance of the Southern Coalfield to the region and the State

NSW is in the unique position of possessing vast reserves of high quality, economically recoverable coal. The State's economy has developed using affordable, reliable electricity generated by coal-fired power stations and steel produced with coking coal from the State's Southern Coalfield. In export markets, there is high demand for NSW's thermal and metallurgical coals as a result of growing electricity and construction demands internationally, coupled with NSW's reputation as a high quality producer, with reliable supply chains, using world class infrastructure.

There is no denying that the coal industry makes a significant contribution to both the economic and social prosperity of NSW residents, and that mining companies play active, positive roles in the local communities in which they operate. The mining industry in NSW's Southern Coalfield is no exception, having had a long history in the region and being uniquely placed as the only source of high quality coking coal in the State.

3.1 NSW coal industry

Mining and minerals processing directly account for 2.5% of NSW's Gross State Product (DSRD 2007). In 2005-06 the NSW coal industry produced 161.3 million tonnes (Mt) of raw coal, yielding over 124.71 Mt of saleable coal. This accounted for over $7.0 billion in income, or 77% of the total value of the NSW mining sector (DPI 2006).

The majority of coal produced in the State is thermal coal, which is primarily used by electricity generators in both domestic and foreign markets. The remaining coal produced is a variety of coking (metallurgical) coals used in the production of steel (DPI 2006).

Domestic consumption of 34 Mt of coal by the power, steel and other industries in 2005-06 totalled over $1.5 billion in value. However, the primary market for NSW coal is the export market, with over 70% of coal produced exported during 2005-06 (DPI 2006). Exports of 89.8 Mt of thermal and metallurgical coal, 80% and 20% respectively, totalled approximately $6.7billion in value (DPI 2006) making coal the largest merchandise export in NSW (DSRD 2007). The average export price for thermal coal in 2005-06 was A$65.02/t while the average export price for metallurgical coal was A$141.13/t (ABARE 2007), meaning that the contribution of metallurgical coal to export value is greater than its contribution to export volume.

The coal mining industry in NSW continues to be a major employer. At the end of June 2006 there were 12,658 people directly employed in the five coalfield regions across the State. This was an increase of 1,368 positions (10.8%) compared with June 2005 (11,290 positions) and the highest level of employment in the industry since 2000. Over the period from June 2000 to June 2006, employment in NSW coal mines rose 32% (3,075 jobs) (DPI 2006).

Over the past decade employees in the mining industry have consistently earned the highest average weekly earnings out of any sector in the NSW economy. During 2006, average full-time adult weekly earnings for employees in the NSW mining sector was $1,880.50 – 27% higher than the second ranked industry, and 67% higher than the average weekly earnings throughout all sectors of $1,123.30 (ABS 2006). The average wage in the NSW coal mining sector was even greater at $2,008.50 (DPI 2006).

Coal mining also contributes to State Government revenues via royalties and other taxes and charges. The royalty rate for coal is between 5-7% of the value of coal extracted. During 2005-06, royalties from the mining industry totalled $504 million, of which coal mines accounted for $447 million. In addition to royalties, mining companies pay other State Government taxes and charges such as stamp duty and payroll tax. During 2005-06, these charges amounted to $100 million bringing the funds paid to the State Government to a total of $604 million. This large contribution from the mining industry to State Government revenue creates benefits for all NSW residents. This revenue may be directed towards public infrastructure, health facilities, education, social security, or one of the many other areas of State Government expenditure.

Forecasts for the NSW coal sector are strong, with the Australian Bureau of Agricultural and Resource Economics (ABARE) predicting continued growth in demand for thermal coal and coking coal (DPI 2006). Hence, NSW coal production is expected to continue to be a significant contributor to the State economy.

Information specific to the Southern Coalfield is provided below.

3.2 Southern Coalfield

Production in the Southern Coalfield accounted for 10.13 Mt, or 8.3% of NSW's total production of saleable coal in 2004-05, and 10.72 Mt, or 8.6% of NSW's total production of saleable coal in 2005-06 (DPI 2006). This is a significant proportion of the State's total output, and shows the importance of the Southern Coalfield to NSW's coal industry as a whole. The Southern Coalfield provides the only source of hard coking coal in NSW. Hard coking coal is used in blast furnaces during the production of steel. Because hard coking coal is much rarer than other types of metallurgical coal and thermal coal it demands the highest price per tonne on the international market, with prices reaching double that of thermal coal in recent years (DPI 2006). For this reason, the relative value of Southern Coalfield production is greater than the relative volume of Southern Coalfield production on a State-wide basis.

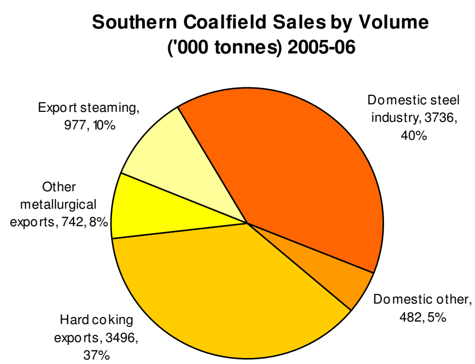

Figure 1 – Southern Coalfield Sales by Volume ('000 tonnes)
2005-06
Source: DPI 2006

The estimated value of saleable coal production in the Southern Coalfield in 2005-06 is about $1.4 billion (DPI 2006). Exports from Southern Coalfield mines were an estimated $640 million[1] during 2005-06, just under 10% of the total export value of NSW coal. During this period, 24% of the 17.9 Mt of metallurgical coal (hard coking coal and other metallurgical coals) exports from NSW were produced in Southern Coalfield mines, including 99.5% of the 3.5 Mt of hard coking coal exports (DPI 2006). These figures demonstrate the significant market share of Southern Coalfield mines in the metallurgical coal market.

With regard to electricity generation a number of mines in the Southern Coalfield extract coal seam methane (CSM) and pipe it to gas fuelled engines to generate electricity. The Southern Coalfield has the largest installed capacity for CSM electricity generation in the State – approximately 100 megawatts in total. This amount is sufficient to power approximately 65,000 homes – a significant contribution to the State's generating capacity while at the same time reducing the release of greenhouse gases into the atmosphere.

From June 2000 to June 2006, direct employment in the Southern Coalfield rose 77% from 1,406 to 2,489 (DPI 2006). This figure does not include full-time contractors which make up a significant proportion of the total workforce. This growth in employment shows the strength of the coal mining industry in the Southern Coalfield.

[1] This figure was calculated using the average value per tonne per type of coal exported.

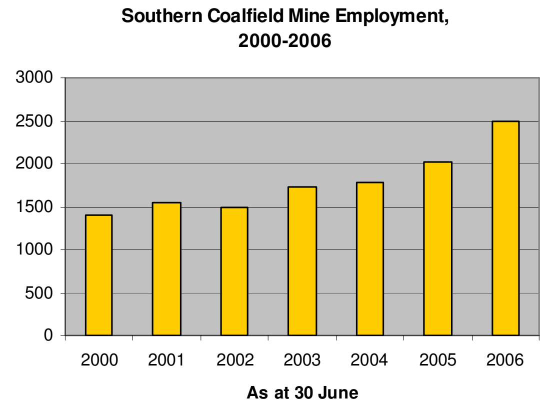

Figure 2 – Southern Coalfield Mine Employment 2000-2006
Source: DPI 2006

3.2.1 Flow-on effects from the Southern Coalfield

Coal production from the Southern Coalfields has both backward and forward linkages to the regional economy.

Forward linkages
Forward linkages refer to impacts on sectors or businesses utilising coal as an input to their production process or handling coal once it is produced. The most significant forward linkage in the region is to BlueScope Steel which sources most of its coal requirements from the Southern Coalfields. The Steelworks coal blend has been optimised around the specific properties of the high grade coking coal sourced from the two seams in the Southern Coalfields, the Bulli Seam (No.1 Seam) and the Wongawilli Seam (No. 3 Seam). Limiting availability of coal from these seams could have a major impact on the Steelworks as currently there is no single coal resource that could replace the No. 3 Seam coal required for the Steelworks. Relying on alternatives from Queensland would impose a cost penalty of at least $20 per tonne and reduce the international competitiveness of BlueScope Steel. It would also impose additional infrastructure costs on BlueScope Steel as an upgrade to the Port would be required to facilitate this.

The Port Kembla Coal Terminal (PKCT) is a key coal exporting facility on the NSW east coast, 72 km south of Sydney. It services the Southern and Western coalfields of New South Wales, exporting high quality coking and steaming coal to customers around the world (http://www.pkct.com.au). The Coal Terminal receives coal by road, rail and barge and has two berths and three shiploaders. PKCT exports around 10 to 11 million tonnes of coal and coke per annum with capacity up to 15 million tonnes (http://www.kemblaport.com.au/?page=51).

Backward linkages
Backward linkages are associated with expenditure that stimulates other sectors in the economy from both purchases made by coal mines in the regional economy as well as expenditure by employees.

A number of factors serve to maximise the production-induced effects of coal mining in the Southern Coalfield on the Illawarra economy. Firstly, coal mining requires significant magnitudes of operational expenditure, much of which is captured by the regional economy because of the long history of coal mining in the region and the development of specialised suppliers. An NSWMC survey during the year 2004-05 found that 55% of mines' expenditure went to suppliers within the region. Secondly, the majority of employees in the Southern Coalfield reside in the Illawarra region which combined with the relatively high wages of the coal sector provides potential for substantial consumption-induced flow-ons. In this respect, a NSWMC survey of 6 of the 8 mines operating in the Southern Coalfield during 2004-05 found that 73% of the wages paid to employees were to those from within the Illawarra region.

Multipliers can be used to summarise the total economic effect of coal mining in the Illawarra Region in relation to the direct effect of coal mining. Employment ratio multipliers for capital intensive industries such as coal mining tend to be high because the direct employment is relatively low compared to the level of expenditure in the regional economy with this high level of expenditure in the regional economy generating a high level of flow-on employment. Employment multipliers of the mining industry have been estimated in the range of 4.5 (ACIL Tasman 2007) and 5.87 (IRIS 2005).

3.2.2 Social significance of the Southern Coalfield

Community Infrastructure

Coal mines in NSW are the lifeblood of many local communities in which they operate. The Illawarra region has a long history of coal mining dating back to the mid-1800's, and many local families have associations with Southern Coalfield mines. This history has helped build strong relationships between mines and local communities, which have been further strengthened through formal and informal consultation processes.

Coal mining in the Southern Coalfields has also provided work opportunities and hence contributed to population movement into the region and retention of population in the region. This contribution to the workforce and populations of regions and towns may well have implications in relation to the provision of and access to community infrastructure and human services, such as health and education facilities, since government provision of these facilities is fundamentally driven by population growth and demographics.

Funding of local development and community programs

The Southern Coalfield mining industry funds a large range of community groups, activities and projects which contribute to the economic and social fabric of the region. Some of the areas funding is directed towards include: arts and culture; community welfare; education; environment; health, sport and recreation and community enhancement programs.

A NSWMC survey during the year 2004-05 found that the total level of direct community investment from the mines surveyed (75% of the total) was $737,000 (NSWMC 2007). This investment was primarily in the areas of education and training, sponsorship and community health.

During this period Illawarra Coal directly contributed over half a million dollars to the local community through donations and sponsorships (IRIS 2005). The community is able to participate in the decisions on where this money is spent through the establishment of two community groups that will decide on the future allocation of community funding, creating a greater level of community awareness and ownership of the expenditure of these funds. Illawarra Coal has also allocated $1 million to its Community Enhancement Program which will be directed towards regional business, education and environmental initiatives.

Community consultation

Public consultation is an integral part of any proposed mine's approval process. As well as requiring a mining title under the *Mining Act* 1992 (Mining Act), development consent or project approval must be obtained under the *Environmental Planning and Assessment Act* 1979 (EP&A Act) before a mining project can go ahead. The process for obtaining development consent or planning approval includes extensive provisions for public consultation and input into the development of specific projects.

The NSW mining industry is committed to fostering positive relationships between mines and the communities in which they operate. Best practice community engagement is strongly supported throughout the industry, and the NSWMC helps facilitate the continual improvement of community engagement practices.

The industry's annual Environment and Community Conference last year hosted the inaugural Excellence Awards presentations, which recognise outstanding environmental and community initiatives that go beyond regulatory requirements and set new standards for best practice in the industry. Southern Coalfield mines were well represented in the finalists in last year's community engagement category. NSWMC has also developed a handbook and training course to assist the industry with its community engagement. Industry initiatives such as these demonstrate the proactive approach taken by the NSW mining industry to work with communities and develop mutually beneficial outcomes.

3.3 Future economic potential of the industry

A recent economic study by ACIL Tasman (2006) for the Minerals Ministerial Advisory Council investigated the economic potential of the NSW minerals industry. Using an economic model that forecast domestic and international economic conditions, the study concluded that given an appropriate regulatory environment the Southern Coalfield could increase exports at the rate of 7.8% each year over the years to 2020.

The estimated recoverable coal reserves in NSW total 10,790 Mt and include those resources where conceptual mine planning has been undertaken in mining lease and exploration licence areas. 670 Mt, or 6.2% of these reserves are located in the Southern Coalfield (DPI 2006). These figures do not include resources that are outside existing mining lease and exploration areas, and therefore this figure is likely to increase significantly in the future as further resources are identified and explored. Consequently the regional economic and social benefits of the Southern Coalfields have the potential to continue for many years.

While coal resources in existing mining leases and exploration areas in the Southern Coalfield are sufficient to supply the domestic steel industry well into this century, some collieries may need to close over the next 20 years as reserves within existing leases are depleted (DPI 2006). This highlights the need for continued access to new coal resources in the Southern Coalfield so that both the local coal and steel industries can continue to operate, as well as the local businesses and industries which they support via forward and backward linkages.

One of the most important aspects of access to future reserves is an appropriate legislative framework that gives mining companies the investment certainty required for this capital intensive industry. In recent years, uncertainty around mining approvals has been a significant factor in business decisions in the coalfield.

4 - Subsidence management

4.1 Types of subsidence

Mining induced movements have at least three major components:

- **Systematic subsidence** – the largest horizontal and vertical movements directly above the mined area which typically extends beyond the limit of mining by approximately half the depth of cover to the coal seam (Figure 3).

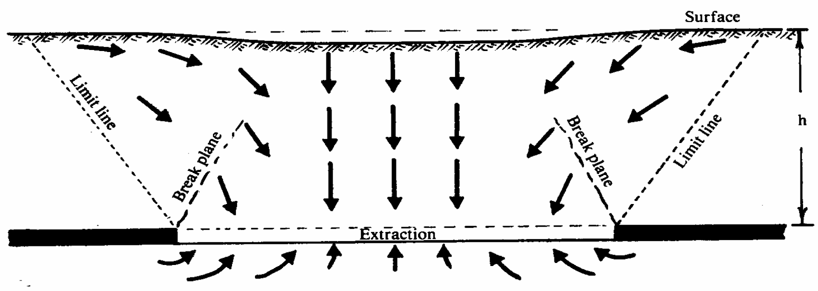

Figure 3 – Normal Mining Induced Movements above an Extracted Area
(after Whittaker, Reddish and Fitzpatrick, 1985)

- **Valley related movements** – closing of the sides of a river valley, accompanied by a rise in the base of the valley, relative to its sides is consistently observed where mining has occurred underneath or adjacent to valleys whether the valley is a deeply incised gorge with sheer cliff lines and exposed rock along the river beds or a small watercourse with gently sloping banks. Valley related movements are observed to a decreasing extent at distances beyond the edge of extraction.
- **Far-field movements** – small and uniform movements at distances well beyond mined areas, which generally reduce as the distance from an active longwall increases. Far-field movements are not normally detectable without the use of specialised monitoring equipment.

Further details on the different types of mining induced ground movements can be found in Appendix 3 – MSEC Report for NSWMC.

4.2 Varying nature of subsidence

Subsidence behaviour varies widely depending on a number of factors specific to each individual situation. Some of the factors influencing subsidence behaviour include:

- **Regional differences in geology** – Regional geological variations result in differing subsidence behaviour between different coalmining regions. The Reynolds Inquiry noted that subsidence behaviour varied significantly between the Southern Coalfield, the Newcastle Coalfield and the Western Coalfield (MSEC 2007).
- **Local differences in geology and topography –** Local geological and topographical variations within coalfields also affect subsidence behaviour. The presence of isolated geological features such as faults, and the mix of characteristics that make each stream unique are just two of the factors contributing to differences in subsidence behavior at the local level (MSEC 2007).
- **Aspects of mine design** – Aspects of mine design such as longwall orientation, longwall widths, pillar widths, extraction height, depth of cover and the proximity of mining in relation to significant features all have an impact on the behavior of subsidence (MSEC 2007). Altering these aspects of mine design is a tool that can be used to manage the impacts of subsidence.

The depths of cover in the Newcastle, Hunter and Western Coalfields are typically shallower and the extracted seams are typically thicker than the Southern Coalfield. This leads to smaller amounts of subsidence in the Southern Coalfield at comparable longwall widths. Valley closure and upsidence is a well recognised and monitored feature of the Southern Coalfield. It has also been observed in the Western Coalfield but is much less significant in the Newcastle and Hunter coalfields as the higher magnitude of subsidence, tilts and strains tend to mask the valley related movements in these coalfields.

The economic value of coal reserves also varies. Some coal reserves are more economical to extract than others, leading to a greater economic and social benefit from their extraction. Applying the same environmental restrictions to all coal reserves would result in vastly different opportunity costs from the forgone coal production and downstream value without necessarily gaining significant environmental benefits.

Mining conditions can differ significantly between different areas and the method of impact assessment for streams and cliffs also needs to address any site specific requirement. The current approval process ensures that each potential impact is assessed on a case by case basis and that appropriate management responses to these assessments are implemented. This site specific assessment methodology is appropriate for the complex nature of subsidence movements and impact assessment.

4.3 Subsidence prediction

Despite claims to the contrary, the science of subsidence prediction is robust. Subsidence prediction models are designed to provide of a range of possible subsidence values rather than attempting to provide absolute values (MSEC 2007). For this reason, observed levels of subsidence are within predicted levels in the vast majority of cases; e.g. out of the approximately 100 cases using the ACARP upper bound incremental upsidence and closure prediction method, only 4 have exceeded predicted values (MSEC 2007).

Prediction methods for each type of subsidence are described below.

4.3.1 Systematic subsidence

An empirical approach has generally been adopted for predicting mine subsidence movements in the Southern Coalfield. The Incremental Profile Method has been used to predict subsidence parameters for all current longwall mining operations in the Southern Coalfield. This method has been found acceptable in a number of Commissions of Inquiry, including those for the Dendrobium Mine and Tahmoor Colliery and has been reviewed and accepted many times in Development and SMP Applications.

The Incremental Profile Method has been found to have a reasonable correlation between observed and predicted subsidence profiles and a good correlation between observed and predicted maximum subsidence. Empirical methods of subsidence prediction are generally accepted as providing predictions of maximum subsidence to an accuracy of ± 10% to ± 15%. When the predictive graphs used in the Incremental Profile Method have been calibrated to local data, even greater accuracies have been found to be possible when predicting the maximum values of the subsidence parameters.

4.3.2 Valley related movements

While the Incremental Profile Method is useful for predicting normal systematic subsidence movements, it does not provide predictions of non-systematic movements, such as those found in valleys. The development of the predictive methods for valley closure and upsidence are the result of relatively recent research and while they do not have the same level of confidence as the predictive methods for systematic subsidence they can be used as long as suitable factors of safety are applied.

The experience gained so far in using these methods indicates that they have generally been extremely conservative. Detailed monitoring programs are in place to provide the data to improve the understanding of upsidence and closure and this will assist in making future predictions. With this understanding appropriate management principles can be applied to account for the probability of actual movements exceeding predicted movements.

4.3.3 Far field movements

A conservative empirical method of prediction for far field movements was proposed in an ACARP report by Waddington Kay & Associates (2002) (now MSEC). In recent times, additional movement data has been gathered and predictions have been provided in terms of probability. For example, predictions of movement and differential movement can be provided based on the average of all previously measured data. Alternatively, based on a frequency distribution of all previously measured data, predictions can be provided for a 1 in 100 chance or a 1 in 100,000 chance, and so on.

4.3.4 The precautionary principle

One of the guiding principles of the National Strategy for Ecologically Sustainable Development is the “precautionary principle”.

Because of the complex nature of subsidence, predicting precise values of subsidence is not feasable – similar to many other types of forecasting activities. It is for this reason that subsidence models provide conservative predictions. This conservatism is an inbuilt precaution that accounts for the uncertainty involved in prediction, and gives decision makers the confidence required to assess environmental risks and include these risks in an assessment of the benefits of a project to society. This information will help to choose appropriate measures to reduce risks to acceptable levels and improve the net benefit of the project to society (mine design, mitigation, remidiation measures).

Where impacts do occur, it is important to determine if they were predicted and approved as part of the assessment process. Where some of the more publicised subsidence impacts have occurred in the past, no impact assessments were actually completed prior to mining because of the regulatory and social framework which existed at the time; e.g. lower Cataract River at Tower Colliery and the upper Bargo River at Tahmoor Colliery (MSEC 2007). These case studies are not appropriate to be used as examples of contemporary subsidence prediction and management within the current regulatory framework. In more recent examples, such as the Georges River, predictions of fracturing and water loss were included in the impact assessment and approved by Government based on the ability to mitigate and rehabilitate these effects. As predicted, there were impacts to the Georges River from subsidence movements that have since been rehabilitated.

4.4 Impacts of subsidence on natural features

After ground movements have been predicted, assessments are made regarding the potential impacts of these movements on the environment. Given that much of the Southern Coalfield has a rugged topography with deeply incised river valleys, it is not possible for coal mining to avoid all impacts on natural features.

When assessing the impacts of subsidence on natural features, the nature of the impacts and the nature of the environment is important to consider:

- **Impacts may be temporary** – Natural or active rehabilitation may result in different levels of impact in the short term to those that may occur in the medium to long term. For example, natural revegetation of an area subject to vegetation dieback from methane gas emissions resulted in a reduction in the level of vegetation impacts (Biosis Research 2007). In the majority of cases, the economic and social cost of avoiding all impacts has outweighed the environmental/social benefits.
- **Impacts may be localised** – The impacts may be localised and insignificant in a regional context. For example, draining of some pools in a stream may be significant in regard to that stretch of stream, but not to the aquatic ecology throughout the length of the stream or within the region. Impacts from mining in the Southern Coalfield should always be considered within the context of the whole sandstone plateau in the Illawarra region.
- **The nature of the receiving environment varies** – Environmental and social values also vary widely from place to place. An impact on a certain type of natural feature in one place does not necessarily equate to an equal impact on the same type of feature elsewhere. This is because the environmental or cultural value of a feature differs according to the significance of the feature’s environmental or cultural attributes. For example:
    - A deep saline aquifer with no human or ecological utility is not of the same value as a shallow, fresh water aquifer that supports groundwater dependent ecosystems.
    - A cliff face with aboriginal drawings or of cultural significance is not of the same value as a cliff face with no cultural or ecological significance that is rarely seen by the public.

To quote Biosis Research (2007:10) "…there is a broad range in the extent of habitats and ecological attributes present, indicating that the nature and extent of impacts may vary greatly depending upon the location of mining".

- **Impacts are relative to other natural and anthropogenic processes** – It can be difficult to decouple the impacts of mine subsidence from other natural and anthropogenic processes in the region. For example, changes to overhangs (e.g. weathering) can occur naturally in the absence of mining (Biosis Research 2007) and it can be difficult to distinguish between mining-induced changes and natural variability occurring within terrestrial and aquatic ecosystems (Biosis Research 2007). It is important to try to differentiate what is an impact of mining, what occurrences may have been accelerated by mining and what occurrences have occurred naturally.

The likelihood and degree of environmental impacts resulting from subsidence movements and effects is not a simple 'yes' or 'no' answer. It is important to note that mining induced ground movements at a point on the surface do not automatically result in adverse environmental impacts at that point (MSEC 2007). It is possible for ground movements to occur as a result of underground mining without the occurrence of cracking; e.g. far-field movements. Some of these movements are only detectable with the use of specialised monitoring equipment and are only of a concern for major infrastructure such as dams or bridges (MSEC 2007). Where ground movement results in subsidence effects (e.g. cracking), the effect may alter the social/aesthetic value of an area, however it does not in all cases result in environmental impacts. For example, in relation to surface bedrock and soil cracking, Biosis Research notes that "while landscape alteration has occurred there is little to no evidence that vegetation or fauna habitats have been altered as a result such that terrestrial ecological functioning has been significantly impacted" (2007:15).

4.4.1 Impacts on rivers and significant streams

Mining has occurred under many streams and other bodies of surface water in the Southern Coalfield.

Streams can experience a number of potential impacts as a result of mining, many of which have been well documented (Holla and Barclay, 2000). A summary of potential impacts is listed below:

- Fracturing of riverbeds and rockbars
- Water flow diversion to the shallow sub-strata
- Additional ponding, flooding or desiccation
- Additional erosion
- Changes to stream alignment
- Changes to water quality
- Release of gas from near-surface strata
- Impacts on terrestrial and aquatic flora and fauna

The extent, severity and manner of impacts vary between different streams and different coal mines because each situation is different. Each of the major streams in the Southern Coalfield is unique in terms of its mix of characteristics, which include flow conditions, water quality, gradients, valley depths and degree of incision, sediment and nutrient load, ecosystems and geomorphological setting including races, pools and rockbar features. The nature and extent of mining beneath or near these streams also varies considerably in terms of the proximity of the extraction to the stream, the size of the extraction and the depth of cover.

This complexity of factors requires impact assessments for mining applications to be undertaken on a case by case basis. There are, however, a number of common themes that can be found in each case. The three impacts referred to specifically in the Panel's Terms of Reference are addressed in further detail below. Again, it is important to consider these impacts in light of the whole Illawarra region, as some localized impacts may be insignificant in a regional context.

Water flows

Fracturing of a river bed can cause a diversion of surface water flow to subsurface flows. Fracturing of rock and surface water flow diversion are the most visible and well known impacts associated with mining beneath streams where the bedrock is exposed.

As the distance between an extracted longwall panel and a stream increases, the amount or degree of subsidence movements generally decreases. However, there are also numerous examples where extraction close to, and even directly under a stream, has not resulted in noticeable flow diversion.

Impacts to water flow and quality are highly influenced by the rate of water flow entering the affected stream section. Where there are low flows, water quality impacts can be more noticeable and where there are high flows, the impacts on water flow are less noticeable.

While surface water can be lost from stream sections above mined longwalls, the water is typically only diverted beneath the stream bed for the extent of the affected area, as illustrated in Figure 4. There is no convincing evidence that cracking in creek and river beds causes any net change in the overall water balance of a stream.

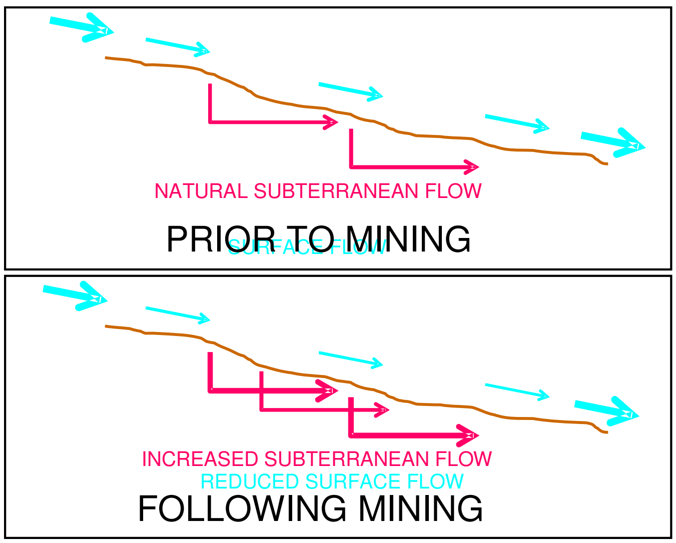

Figure 4 – Diagrammatic Representation of Potential Subterranean Flows

(MSEC 2007)

Connectivity between surface water and the mine is typically not observed in the Southern Coalfield due to the depth of cover between the surface and the mine. Most mines in the Southern Coalfield are dry, with the Bald Hill Claystone aquitard generally restricting vertical connections.

Water quality

Surface water quality datasets are now substantial. There is general recognition that local surface water quality impacts can occur in the form of reduced dissolved oxygen and increased iron oxides and manganese where diverted shallow groundwater re-emerges downstream of an impact site. This is due to enhanced rock-water interactions as shallow groundwater flows past newly opened rock surfaces. Water quality impacts persist for only a short distance downstream of the groundwater discharge point.

Aquatic ecology

In general terms, the following impacts on aquatic ecology may occur as a result of mine subsidence:

- Draining of pools may lead to a reduction in the amount of aquatic habitat and may also affect the distribution of mobile fauna that may have utilised pools for foraging. Interrupted flows may impact passage of fish and invertebrates within watercourses, although aquatic fauna may be able to relocate to unaffected pools.
- Water quality impacts may result in the introduction of dissolved compounds, weathered from newly exposed sandstone in fractured bedrock.
- Gas releases generally do not impact water quality due to the low ability of the methane to dissolve in water. It is possible, if substantial gas emissions occur at the surface that these could cause localised vegetation dieback. These impacts have been limited to small areas of vegetation

and local to the points of emission. The gas emissions have declined over time and the affected areas have successfully recovered.

It is important that the potential impacts described above be placed in context with other natural and anthropogenic processes. Many of the significant creek and river systems in the Southern Coalfield are subject to regulation by various NSW State Government agencies. In some instances, water management policy and not mining activity has affected the ecological functioning of rivers and creeks before, during and after mining.

4.4.2 Impacts on swamps

Many of the upland swamps occurring near the eastern extent of the Woronora Plateau have been mined beneath by both historical board and pillar extraction, or more recently by longwall extraction techniques. Few, if any, impacts associated with mining have been reported in these swamps. Further, observational assessments of swamps that have been mined beneath and swamps that have not been mined beneath would support this observation.

Recently, concerns regarding impacts to upland swamps by underground mining have been the subject of intense investigation and research. Where upland swamps overlie rock fractures there is some concern that they may be drained causing ecological impacts. Concerns have arisen because a small number of upland swamps have exhibited scouring and erosion and these features have been linked to mining impacts by some parties.

The studies have found thatl there is little difference between the current state of swamps that do and do not overlie mining operations. There seems to be no significant difference in surface water between the swamps that have and have not been subject to mining related surface deformation. Surface deformation alone is therefore not likely to dewater swamps in the long term (Biosis Research 2007).

In swamps where scouring has been observed in recent years, it is likely that a combination of events have contributed including: specific geographical attributes of each swamp; dry or drought conditions; disturbance to cover vegetation by fire or other means; and intense rainfall and associated flows prior to the re-establishment of vegetation cover.

4.4.3 Impacts on cliff lines

Mining can result in differential movements along cliffs which induce additional stresses in the rock mass, and as a result, can potentially reduce the stability of cliffs. Historical studies show that the likelihood of cliff instability can increase if mining occurs directly under cliffs. The major factors which influence the stability of cliffs, both naturally and due to mining, include: cliff geometry; geotechnical factors; the local environment; and the mine plan.

The complex interaction of the above factors makes it difficult to develop a model that can predict the likelihood of cliff or rockface instability based on predictions of ground movement. It is likely that in some cases, a rockface is close to a threshold point of instability prior to mining, and even the smallest additional movement may bring forward the timing of a rockfall.

There have been few instabilities in the Southern Coalfield as a result of mining under cliffs at depths of cover greater than 400 metres. Importantly, there has not been one reported instability beyond the edges of longwalls.

Historically, cliff falls, impacts to overhangs, rock outcrops and steep slopes resulting from subsidence in the Southern Coalfield have resulted in only very minor impacts on terrestrial or aquatic ecology. Typically, these changes have resulted in localised short term impacts to vegetation immediately down slope of the failure. Many of these impacts are readily and naturally rehabilitated as vegetation re-colonises the disturbed soil. Landscape changes have the potential to increase erosion of soils which may result in increased sedimentation of waterways. These impacts may potentially disrupt the lifecycle of fauna that utilise overhang or rock outcrop habitats and may, in very rare instances, result in the death or injury to fauna sheltering in such habitats. However, given the low historical prevalence of such falls, direct impacts are likely to be very rare and insignificant from an ecological perspective.

4.5 Assessment of subsidence impacts on natural features

Given the complexities, pinpoint prediction of where fractures may develop in response to mine subsidence is difficult. However, monitoring of past mining experiences provides a good level of confidence for predicting the likelihood, style and extent of fracturing due to longwall mining. Conservative predictions also ensure the appropriate management of all likely impacts.

The assessment of subsidence impacts on natural features generally involves:

- Identification and characterisation of the feature (e.g. location, type, surrounding geology, ecology).
- Prediction of the amount of movement at the feature.
- Assessment of the potential effects on the feature (e.g. changes in water quality or flow, cliff falls) and the impact on the environmental, economic, social or cultural values attributed to the feature.

The impact assessment is based upon a combination of interpreting the predicted movements of subsidence, closure and upsidence, referring to case studies of previous impacts and applying this knowledge to the identified characteristics of the feature.

Due to the complexity of factors involved, the potential for impacts and impact assessments are generally described in probabilistic rather than absolute terms.

4.6 Subsidence impact mitigation and minimisation

Mitigation or minimisation of subsidence-induced impacts can successfully be achieved through a number of methods. These can be passive methods, such as mine design and layout, or more active methods that require mitigation measures or rehabilitation activities to reduce the levels of environmental impact. A summary of the methods available to mitigate impacts on streams is provided below, and these techniques can similarly be applied to other significant features. Some of these methods have been used in the Southern Coalfield while others have been used overseas.

- **Longwall Setback –** The level of impact typically reduces the further a longwall is setback from a stream, as the magnitudes of subsidence, upsidence and closure movements reduce. Recent mining applications have not involved mining directly beneath major rivers and streams in the Southern Coalfield. The appropriateness and distance of a setback between longwalls and streams varies in each case. In all cases a setback will substantially minimise the mining impacts to streams compared to mine plans that might directly mine beneath a stream. Further discussion on longwall setbacks is provided in the text box below.
- **Longwall Design –** The level of impact typically reduces as the magnitudes of subsidence, upsidence and closure movements reduce. Longwalls are currently between 150 and 300 metres wide in the Southern Coalfield, with coal pillars that are approximately 40 metres wide. In some cases the impacts to streams can be reduced if longwall widths are narrowed and pillar widths are increased where longwalls pass directly beneath streams. While narrow longwalls and wide pillars are less economical, this approach can result in less coal sterilisation when compared to a solid barrier of coal under the feature. Alternatively, it is possible to reduce the width of longwalls on the tailgate side in the vicinity of streams only while maintaining more economical longwall widths for the remainder of the longwall.
- **Backstowing –** Subsidence develops as a result of the overlying strata filling the void created by the extraction of coal. One potential method of reducing subsidence is to backfill the void behind the longwall face within the coal seam, to reduce the amount of caving that occurs. This is called backstowing and the practice has been successfully implemented in some places overseas, such as in Germany and Poland. The mining industry in Australia has investigated the feasibility of backstowing with a view towards reducing subsidence related impacts on the surface. At this stage it has been found that not only is the practice extremely uneconomical, there are significant practical and mine safety issues to address with this methodology in Australia. Technological advancements may one day lead to backstowing however. Backstowing does not completely reduce subsidence to zero. The amount of subsidence reduction achieved to date is approximately 50 to 70%.
- **Overburden Grout Injection –** While backstowing fills the voids left within the coal seam, this method attempts to fill voids within the overburden before other upper horizons subside into them.

It is achieved by drilling holes from the surface and injecting grout just ahead of the longwall face into targeted strata layers. The method has been successfully adopted in China and is currently being investigated in Australia through ACARP funding. As with backstowing, the method will not reduce subsidence to zero. There are also significant groundwater and mine safety issues to address with this methodology.

- **Controlled water flow –** The introduction of controlled or regulated flows can minimise short term impacts on a stream and its ecology by maintaining water levels in pools during mining. This practice was adopted, for example, in the Georges River following the mining of Longwalls 5A1 to 5A4 at West Cliff Colliery, and trial releases from Broughtons Pass Weir were undertaken in the Cataract River following the mining of Longwalls 10 to 14 at Tower Colliery. The method may not be feasible as a long term mitigation measure and remediation of surface flow diversion sites must still be undertaken once subsidence movements are complete.
- **Monitoring –** Collieries undertake extensive monitoring in the Southern Coalfield, particularly in relation to monitoring of streams. Monitoring is conducted on ground movements, stream flows, water quality, ecosystem health and visual aspects. It has been incorrectly asserted that monitoring is only beneficial in the long term or that monitoring doesn't prevent an impact from occurring. In the contrary, monitoring can be a useful tool for impact prevention in the short term. There have been many cases where longwalls have mined towards sensitive surface features with triggers for actions, including contingency plans of stopping a longwall short if monitoring indicates that severe impacts are imminent. Alternatively, monitoring during the mining of one longwall can be used to decide whether to alter the planned extent of subsequent longwalls.

Discussion of mandated setback zones around natural features

There have recently been calls from some sections of the community to mandate protection zones around natural features. A figure of 1 kilometre has been suggested for streams (TEC, 2007).

A mandated setback distance is illogical, particularly if a fixed distance is used. It is well known that the extent and magnitude of subsidence related movements are related to many factors including depths of cover, seam thicknesses, and longwall and pillar widths. A fixed protection zone completely ignores all of these factors. It is also well known that the characteristics of natural features vary considerably from ephemeral streams to constant or regulated water flows to stored water, or from small rock outcrops to high cliffs with deep overhangs. Applying a fixed buffer zone completely ignores all of these factors. Finally, a fixed protection zone suggests that all natural features are of equal value and surely this is not supported by all groups in the community.

Appendix 2 displays the effect of a 1km buffer zone on recoverable reserves. It demonstrates that mining in the Southern Coalfield would cease if this barrier were adopted.

An arbitrary one-size-fits-all protection policy clearly does not make sense and will lead to either unintended harm to some natural features if the protection zone is too small, or unnecessarily sterilise valuable coal resources if the protection zone is too large. A mandated setback distance is a political tool, not one based on science.

It is not clear why a 1 kilometre protection zone was suggested for streams, except that references have been made to MSEC's findings on observed absolute far field movements, which were reported in the ACARP report (2002). Impacts generally occur as a result of differential movement, not absolute movement. No physical impacts have been observed in streams located more than 400 metres from a previously mined longwall because differential movements are negligible at such distances. The furthest known minor impacts from longwalls are almost half this distance.

A better approach would be to focus on desired outcomes rather than prescribe fixed limits. A more appropriate contribution to the debate around subsidence impacts in the Southern Coalfield would be to develop principles regarding the acceptable level of impact for natural features such as streams and their environment. This could be developed as policy by the NSW Government in consultation with the community and the mining industry, with input from relevant experts. The policy would aim to find a balance between coal sterilisation and other economic costs and impacts to the environment. The desired outcomes should be best described in terms of probabilistic rather than absolute terms.

To be effective, acceptable levels of impact should be developed on a case by case basis for each identified natural feature. For example, it should be recognised that different levels of impact may be considered appropriate depending on the characteristics of each stream or characteristics of each section of stream. If a section of stream is identified as being particularly significant to the community, a desired outcome might be for an extremely low probability of significant impacts. This policy decision would be made after considering the economic cost of achieving the desired outcome.

If an outcome-based, case by case approach is adopted, rather than a prescriptive one-size-fits-all approach, mining companies can be provided with the flexibility and certainty required to design mine plans that appropriately meet the needs of the community and their shareholders. It also allows decisions on the acceptability of impacts to remain at the planning stage, leaving the SMP process to determine whether the potential impacts from final proposed mine plans are likely to exceed the defined acceptable limits.

4.7 Monitoring of subsidence activity and subsidence impacts

The NSW minerals industry undertakes extensive monitoring of subsidence, particularly in relation to monitoring of streams. Monitoring is conducted on ground movements, stream flows, water quality, ecosystem health and visual aspects. As outlined in the previous section, monitoring can also be a useful tool for impact prevention in the short term. There have been many cases where longwalls have mined towards sensitive surface features with triggers for actions, including contingency plans of stopping a longwall short if monitoring indicates that severe impacts are imminent. Alternatively, monitoring during the mining of one longwall can be used to decide whether to alter the planned extent of subsequent longwalls.

Increasingly over the past decade, mining development consents have included conditions requiring the development and implementation of monitoring programs for a range of natural, cultural and physical parameters. These programs serve to increase the confidence of impact prediction by comparing pre-mining assessments with actual impacts observed during and after mining. These programs have also served to refine the impact assessment process to direct appropriate levels of assessment to those values most at risk of impact from any particular mining proposal.

As a result, the industry is one of the largest providers of funding for ecological and cultural heritage data collection in the region. Further, a great deal of this data not only assists the mining application, assessment and approval process, it also serves to grow the corporate and communal knowledge of these important values across the region.

A typical Water Monitoring and Management Program may contain the following information (Comur Consulting 2006):

- A surface water budget of streams that may be affected by subsidence so that any loss of water can be predicted and quantified.
- Relationships of water levels to ecological processes such as fish migration within streams subject to mining subsidence.
- Descriptions of the water quality and flow characteristics of streams that may be affected by subsidence.
- Trigger levels that may indicate unacceptable effects of subsidence and/or the need for remediation.
- The main areas of current and expected water make within the mine workings.
- Agreed monitoring locations for groundwater and dependent vegetation habitats.
- Hydraulic characteristics of overlying and intercepted groundwater systems, and changes to ground/surface water due to coal extraction and dewatering operations.
- Overlying groundwater dependent ecosystems and surface water environments and potential impacts from coal extraction and dewatering activities to these systems.
- Any pumping tests and groundwater simulation studies undertaken.
- Surface and groundwater monitoring, including: volumes extracted from mining areas, groundwater level, electrical conductivity, total dissolved solids, pH, alkalinity, turbidity, dissolved oxygen, temperature, iron, and manganese.

Details of monitoring of other impacts are provided below:

- In a similar way to the assessment of impact due to mining, terrestrial flora and fauna monitoring in the Southern Coalfield aims to target values associated with landscape alteration. In the past decade terrestrial ecological monitoring programs have been designed and implemented for some approved mine developments for the following values: creekline, ridgeline and upland swamp vegetation monitoring; creekline and ridgeline tree mortality monitoring; and habitat usage by fauna including bird, reptiles, amphibians and invertebrates in creek, ridge and swamp habitats.
- Best practice in monitoring of aquatic ecosystems includes replicated sampling of selected ecosystem components (“variables”) at sites at risk from subsidence and at control sites; and sampling at all sites before, during and after the longwalls impact the watercourses. It is also beneficial if several measures of pre-subsidence conditions can be obtained. This also helps in understanding pre-existing effects of other human activities (e.g. flow regulation).
- Monitoring of subsidence effects on cultural heritage sites tend to be archaeologically focused, and concentrate on impacts to sandstone shelter sites, particularly those containing art. It is important that monitoring programs attempt to measure the extent of natural weathering and note areas of natural instability to ensure results provide some level of certainty as to the specific subsidence mechanism that may impact a site.

The development, implementation and reporting for monitoring programs has been subject to a great deal of scrutiny from NSW Government Agencies including the NSW Department of Environment Climate Change (formerly Department of Environment and Conservation) and the NSW Department of Primary Industries (Fisheries) and in some cases open to peer and public review.

4.8 Subsidence impact remediation

Remediation of subsidence impacts may occur naturally, or may involve active intervention.

Where the conditions are right, some streams naturally recover from subsidence impacts. Conditions which promote natural remediation include consistent water flows, relatively flat gradients and the existence of a sediment or nutrient load. Typically natural remediation occurs over a long period of time, although occasionally natural remediation has occurred in the short term.

A number of mining companies have sealed fractures in stream beds to minimise impacts on streams. Methods of remediation have steadily improved over time as a result of increased knowledge and experience and availability of improved sealing products and techniques. More recent work to remediate sites such as pattern grouting of rockbars in the Georges River has been very successful. While remediation can minimise the long term impacts of mining, there remains a period during active subsidence where short term impacts under low flow conditions can still eventuate.

The discussion of subsidence mitigation and remediation needs to balance a number of pertinent issues. These include:

- The level of impact needs to be clearly quantified and deemed appropriate to warrant action. That is, subsidence may impact features that are of low ecological value such as already polluted drainage lines which may not warrant the implementation of expensive and long term monitoring and impact remediation. The relative significance of impacts in the context of the whole region should also be reviewed before determining appropriate remediation efforts.
- The level of required mitigation and remediation needs to be clearly understood in terms of both safety and also the impact the rehabilitation measures themselves may have. Active rehabilitation at the remote location of many of the areas subject to subsidence in the Southern Coalfield may require the disturbance of otherwise undisturbed habitat. It will be important to ensure that the level of impact for the remediation is comparably less than the subsidence related impacts they seek to remediate.
- The level of 'background impact' on natural features needs to be well understood to ensure that rehabilitation activities are targeted at processes induced by mining and not natural or background processes, e.g. induced rockfalls in some areas, particularly along the Illawarra Escarpment. It is important that regulators and the industry alike consider the rate and prevalence of 'background impact' that may occur prior to the commencement of mining to ensure that inappropriate remediation is not required or applied.
- Any remediation activities need to be balanced with the existing land and water management strategies in order to ensure that the level of required and proposed remediation is commensurate with the impact of subsidence alone. For example, in the well publicised incident of flow redirection within the Cataract River the final determination to list 'Alteration of habitat following subsidence due to longwall mining' a Key Threatening Process states that 20% of the reduced flows in this area were directly attributable to reduced water flows regulated by Sydney Water.

5 - Risk management approach to subsidence impacts and management

As with any major project, once the science of impact assessment and mitigation is understood there is a need to determine how economic benefits of the project compare to the environmental costs. This section outlines the minerals industry's risk management approach to this decision-making and economic trade-off.

5.1 Economic trade-off framework

For new coal mining proposals as well as existing operations, the appropriate method for considering economic efficiency (community desirability) of coal mining in the Southern Coalfield is benefit cost analysis (BCA). In this framework the social benefits of a proposal are compared with the social costs. Where the present value of benefits exceeds the present value of costs the project is considered to be economically efficient.

It follows that in this economic efficiency framework that the existence of environmental impacts - even significant environmental impacts - is not sufficient justification to reject a coal mine proposal on economic efficiency grounds. What is relevant is the comparison between the net production benefits of coal mining and the environmental impacts.

Increasingly this type of analysis is being undertaken as part of the Environmental Assessments for coal mines, for example Wambo (Hunter Coalfield), Wilpinjong (Western Coalfield), and also for Metrolopolitan Colliery. However, often the analysis stops short of primary studies into the economic value of potential environmental impacts. Because of the limited number of relevant existing environmental valuation studies that could be used for benefit transfer, coal mine BCAs instead rely on threshold value analysis where the net production benefits of coal mining are compared to a qualitative consideration of the potential environmental impacts.

Nevertheless, because of the considerable producer surpluses that arise from many coal mines and the extensive mitigation measures incorporated into a project design, often the community would need to value residual environmental impacts, after mitigation, very highly for the costs of environmental impacts to outweigh production benefits.

Even if a BCA of a particular project indicates that the net benefits of coal mining exceed the environmental costs, this does not mean that the project design has optimised the net benefits for society from the Project. With underground mining the design of the project inevitably involves a trade-off between the quantity of coal recovered (i.e. producer surplus) and environmental impact costs to the community (i.e. consumer surplus).

Part of this trade-off story, the potential impacts of subsidence and proposed management approach, is currently examined via the Subsidence Management Plan approval process utilising a risk management framework. Preparation of SMPs is directed by the NSW Department of Mineral Resources "Guidelines for Applications for Subsidence Management Approvals". SMPs are required to be prepared under the conditions of mining leases for all potential mining-induced subsidence impacts and approval is required from the Director-General of the Department of Primary Industries (DPI) formerly the Department of Mineral Resources. Environmental Assessments prepared under Part 3A of the EP&A Act also require a consideration of environmental risks (i.e. pre and post mitigation/avoidance).

A SMP essentially involves:

- Outline of the mining system and resource recovery;
- Characterisation of surface and subsurface features within the Application Area;
- Subsidence prediction;
- Assessment of likely subsidence impacts – consequence and risk; and
- Proposed subsidence management.

This process includes consultation with the community and relevant state and local government bodies. Indeed, the DPI and other state authorities such as the Sydney Catchment Authority participate in workshops and risk assessments to prepare SMPs.

The Guidelines encourage and promote communication between parties in an “attempt to find a solution which optimises benefits to the community”. A consensus solution is always sought. However, where consensus is not possible, the DG makes a decision based on the available information.

Consistent with the Guidelines, the level of detail and depth of analysis required for all aspects of an SMP application is commensurate with the scale and significance of the anticipated subsidence. Hence SMPs will vary on a case by case basis.

This current risk assessment process, embedded in SMPs, clearly identifies the predicted subsidence and environmental impacts of proposed underground mining, and has been used as a basis for planning for and implementing remediation works, where warranted.

It is important to understand that the process has been very successful in identifying when impacts are likely to occur and the nature of these impacts. While in some instances some members of the community may not be satisfied with the level of impacts, these impacts have been comprehensively assessed and predicted in SMPs, and government decisions taken knowing the likely consequences.

While the industry generally supports the SMP process it can be considered to have a number of deficiencies:

- There has been a lack of communication to interest groups and the public of the expected, and Government accepted, subsidence impacts of underground mining.
- There has been a lack of communication to interest groups and the public that approved mining is expected to have some environmental impacts.
- The SMP process and associated risk management analysis is used by industry to develop mining proposals that it considers are likely to be acceptable to Government rather than considering the optimal outcome for the community.
- The way the SMP process is currently implemented considers only one half of the economic trade-off i.e. potential environmental impacts, with no consideration given to the value of coal sterilised in minimising environmental impacts.
- By proposing mining that it thinks will be acceptable to Government, Industry is making decisions to sterilise large quantities of coal resource prior to preparation of SMPs.
- Even when considering only one side of the economic trade-off, this consideration has been undertaken largely in a qualitative way with no consideration of the community’s valuation of environmental impacts, so that environmental damage costs can be placed in a trade-off analysis with mining benefits. This leaves the process susceptible to “rent seeking”[2] from environmental interest groups.
- In the absence of a more comprehensive economic trade-off analysis, the SMP process can be vulnerable to subjective setting of risk threshold scores that are considered “not tolerable” without knowledge of the opportunity cost to society and environmental benefits of setting them.

A more comprehensive description of the economic trade-off analysis is provided in
Appendix 6 – Gillespie Economics Report for NSWMC, using a hypothetical environmental restriction on coal mining around significant features.

Where the magnitude of environmental benefits or the resource implications of different environmental restrictions are uncertain it is possible to supplement the trade-off analysis through sensitivity testing or applying probabilities to outcomes i.e. an expected value approach. The economic trade-off analysis can therefore build on the existing SMP framework.

The following important lessons can be gleaned from the economic trade-off framework:

- There is always some trade-off with underground mining between the quantity of coal recovered and environmental damage costs to the community.

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[2] Rent seeking refers to individuals or groups in society attempting to obtain outcomes that benefit themselves rather than outcomes that are best for society.

- Environmental restrictions impose opportunity costs on society in terms of the value (producer surplus) of coal production foregone but may also provide environmental benefits.
- The optimal level of environmental restriction is where the marginal opportunity costs of foregone coal production are equal to the marginal environmental benefits of the restriction.
- Some level of environmental damage will almost always be optimal in the case of underground mining. Any paradigm that suggests no environmental damage or only minimal environmental damage is acceptable is likely to be economically inefficient.
- The imposition of a single environmental standard for natural features in the Southern Coal field is also likely to be economically inefficient and impose considerable costs on society. For instance, a 1 km buffer to streams (as suggested by some) is likely to result in the majority of the Southern Coalfield’s future economic benefit being lost due to coal sterilisation. The optimal level of environmental restriction will vary from situation to situation. A lesser environmental restriction will be optimal the steeper the MC curve and the smaller the environmental benefits of imposing environmental restrictions. A greater level of environmental restriction will be optimal the flatter the MC curve and in situations where there are greater environmental values are at stake.
- A not uncommon situation is likely to be one where the optimal level of environmental restriction is zero (refer to the case study in section 5.2).
- It should also be noted that in some instances where there is a trade-off between the quantity of coal recovered and environmental damage costs to the community it may be technically feasible to remediate environmental impacts to a point where environmental damage is negligible thus internalising the externality cost of the mining activity and requiring no environmental restriction.

5.2 Case study of trade-off framework

The following case study illustrates the potential trade-off between coal production and environmental damage costs. It is based on a real situation in the Illawarra Region.

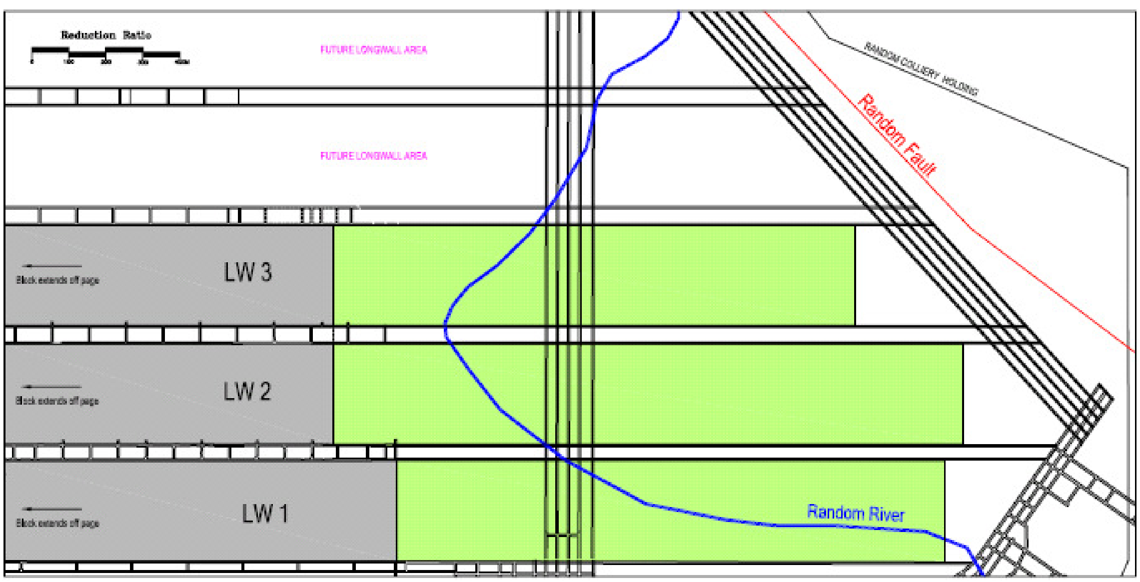

Figure 5 – Case Study Scenario 1 – Full Mining

Scenario 1 involves full mining to the extent limited by the geological fault rather than the river. This level of mining will have some environmental impacts. Extensive studies into the nature of ground movements have determined that there will be significant ground movement at the river. The river will compress horizontally as the subsidence develops and this will cause existing bedding planes to move in isolated areas. Relevant case studies have shown that the following impacts will be experienced:

- There will be no net loss of water from the river.

- Some of the surface flows will be diverted underground, but these flows will re-emerge a short distance down stream (in a similar manner to the natural diversions that exist in the area, pre-mining).
- Most of the cracking caused by subsidence will not be perceived by humans due to the existing base flows in the river. It has been assessed that the base flows are sufficient to charge the new cracks such that surface flows will continue, notwithstanding the fact that some flow has been diverted below the surface.

The assessment has determined that two impacts of concern may arise:

- The presence of mining induced cracking in a location where bushwalkers would notice (ie, to the side of the main channel). The area in question is rugged terrain and requires a reasonable fitness level and a full day to enjoy the walk in and out. Assessment of the bushwalking activity has found that these parts are visited at the rate of 100 man-trips per year; and
- the possibility of draining an existing pool.

It has been assessed that the consequence of these impacts is mainly aesthetic rather than ecological.

The economic value of this environmental damage can be estimated using benefit transfer and a number of conservative assumptions.

Based on a consumer surplus per bushwalking trip of AU$30 the annual economic value of this activity at the site is AU$3,000, or over a period of 10 years this activity has a present value of AU$21,000. Assuming that as a result of the subsidence this entire recreation activity is lost, the damage cost would be AU$21,000. Furthermore assuming that water quality along 5% of the river is affected by iron hydroxide leachate (i.e. a change from water quality suitable for direct human contact to water quality only suitable for indirect recreational uses such as boating), then based on Bennett and Morrison (2001) this environmental damage would be valued at AU$14 million. Again this assumption is overly pessimistic since analysis suggests that at most 2% may be temporarily impacted by iron hydroxide leachate.

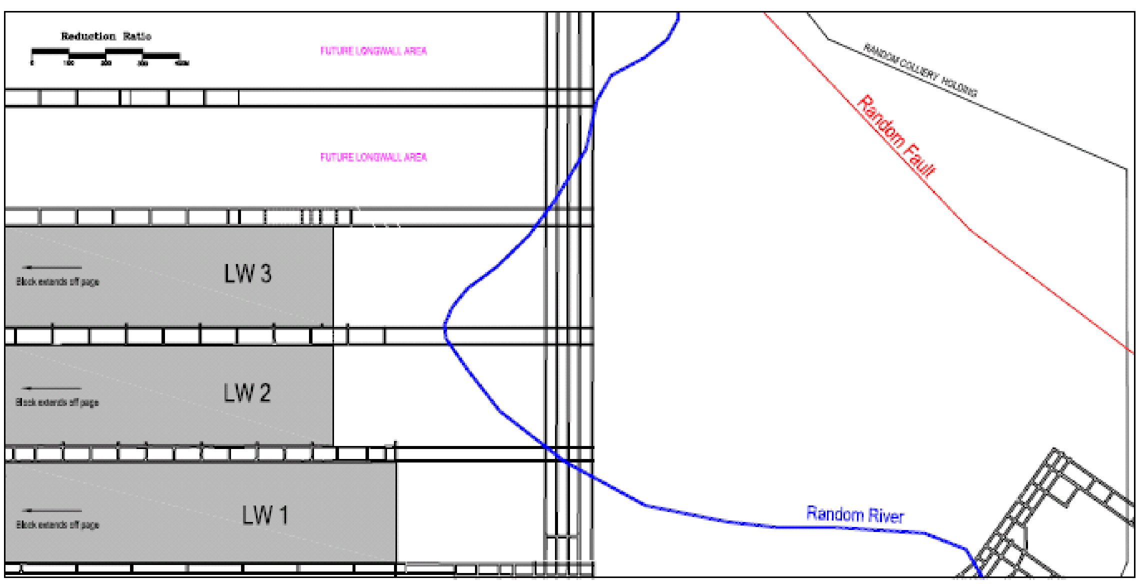

Figure 6 – Case Study Scenario 2 – Mining to 300m of River

Scenario 2 involves a modified layout with coal extraction at a distance of 300m from the river and continuing in a direction away from the river. Under this scenario, the portion of coal between the fault and the river is not sufficiently wide for additional longwall blocks and there are no economic prospects for it.

The green-shaded increment of longwall coal that has been sterilised from the three longwalls by this layout is 4.40mt (based on 2.5m thickness, and 1.4 t/m^3) comprising:

- 1.42mt from LW1;

- 1.63mt from LW2; and
- 1.35mt from LW3.

The gross value of this foregone coal production is AU$466 million. Producer surplus associated with this foregone coal production can be estimated by adjusting for the marginal costs of extraction, giving a value of AU$314 million[3].

The environmental benefits of the mining configuration of Scenario 2 involve avoiding the environmental damage costs that would occur under Scenario 1. Extensive studies into the nature of ground movements have determined that under Scenario 2 there will be ground movement at the river, but that there is a low or very low likelihood of these movements having an ecological or riverflow impact.

The impact assessment has also determined that due to the existing characteristics of the area, any impact that does occur is likely to mimic natural movements on existing planes and fractures and is not likely to be perceived without precision survey. The impact assessment has determined that any impact that does occur is also likely to be localised and short-lived.

Assuming that under this scenario all environmental damage costs are avoided, there would be an economic benefit of AU$14.021 million. However, this would come at an economic cost of AU$314 million.

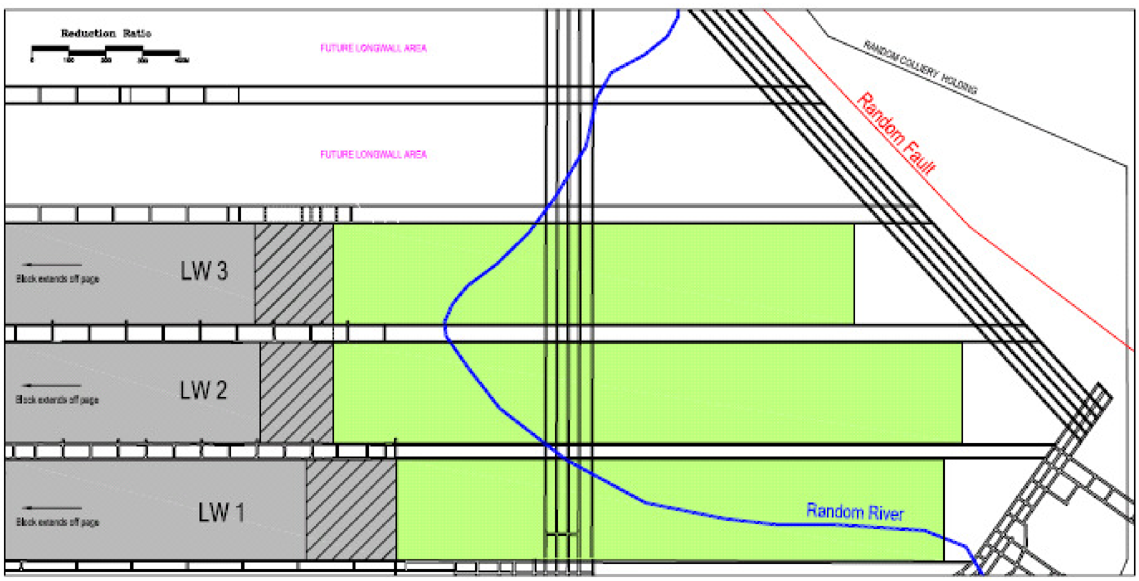

Figure 7 – Case Study Scenario 3 – Mining to 500m of River

Scenario 3 involves modification of the Scenario 2 mining layout so that mining is no closer than 500m from the river (increased from 300m).

The increment of coal that is sterilized from the three longwalls by this layout (shown with hatching) is 624kt (based on 2.5m thickness, and 1.4 t/m^3) comprising:

- 234,000t from LW1;
- 188,000t from LW2; and
- 202,000t from LW3.

The gross value of this foregone coal production is AU$66 million. Producer surplus associated with this foregone coal production can be estimated by adjusting for the marginal costs of extraction, giving a value of AU$45 million.

[3] The marginal costs relate to the running costs of the long wall machinery since other costs are essentially fixed.

Based on the characteristics of the river, and the small magnitudes and nature of the ground movements, it has been assessed that ecological and riverflow gains to be achieved by this change from 300m to 500m are negligible.

Hence, relative to Scenario 2, Scenario 3 would result in an incremental economic cost of AU$45 million but little environmental benefit.

5.2.1 Case Study Conclusions

These scenarios demonstrate that for this particular mine and associated natural features the economically efficient level of environmental restriction is no environmental restriction. It is optimal from society’s perspective to incur some modest environmental damage costs. To limit coal mining would impose opportunity costs on society that are significantly larger than the environmental damage costs that are avoided.

Furthermore, modest rehabilitation costs could be undertaken (AU$200,000) to restore water levels in the pool if mining did cause the pool to drain[4]. No remedy could be undertaken for the man-made scar at the location that may be evident to bushwalkers for a period of up to 10 years.

it is often the case that in SMP approval applications, areas such as those shown in green Scenario 1, may have already been written off at an earlier stage within the mine planning process in the interests of achieving a timely SMP approval so as to secure the business. Governments, in proposing further seemingly minor changes to a layout, may therefore not be aware of the full cost in terms of foregone coal production.

It is not uncommon for mine operators to invest millions in the preparation of the case for SMP approval. This high cost is reason alone for operators to only submit layouts that they consider will meet Government expectations about the balance of responsible resource recovery versus environmental impact. Mine planning takes time, so the focus is usually on the option that is submitted to Government in anticipation of the approved application.

Both these time constraints could be overcome if mine operators discussed their options for different mine plans in the context of the economic efficiency framework early in the process. By presenting a number of options to government very early in the process, the industry could gain confidence about the preferred option which should not prevent simultaneous mine planning. The SMP application could then demonstrate the original options that were discussed with stakeholders as part of the justification for the preferred option being put forward. Early discussions with stakeholders should include a range of government agencies, including the Department of State and Regional Development and environmental regulators.

[4] These costs are influence by ease of access and the number of cracks requiring repair. But even repair costs considerably more than this amount have no impact on the analysis.

6 - Conclusion and recommendations

The report demonstrates that there are many complex site specific factors that can affect the extent and magnitude of impacts to natural features as a result of underground mining. Impact assessments and development of impact minimisation measures can only be completed successfully on a case by case basis.

Subsidence prediction is a robust science. Subsidence monitoring has been tested against observed subsidence data at many collieries in the Southern Coalfield and there is a good correlation between observed and predicted maximum subsidence. With an understanding of the level of confidence around the predictions of upsidence and closure, appropriate management principles can be applied to account for the probability of actual movements exceeding predicted movements on the few occasions that these might occur.

While some impacts have occurred, it is important to recognise that mining induced ground movements at a point do not necessarily result in adverse impacts at that point. Even physical impacts such as rock fractures or rockfalls do not necessarily result in impacts to the environment such as loss of water flows or ecology.

Based on the above findings NSWMC recommends:

- Support for the general SMP process and consideration of environmental restrictions on a case by case basis;
- Recognition by the Panel that the current implicit goal of no or minimal environmental damage of underground mining is unlikely to be economically efficient and it is the Governments responsibility to make decisions that are best for the community as a whole rather than for specific vested interest groups;
- Recognition by the Panel that proposals for set restrictions on underground mining in relation to natural features are unlikely to be economically efficient and will impose unnecessary opportunity costs on society;
- Recognition by the Panel that the current risk management framework embedded in SMPs has been effective in predicting subsidence impacts and that interest group concerns largely revolve around their own view of the acceptability of predicted impacts rather than the acceptability from a whole of community perspective:
- Understanding by the Panel and community that without recognition of the above, industry may continue to be pressured into making sub-optimal decisions to sterilise large quantities of coal resource and ultimately reduce investment in the Southern Coalfield;
- Extension of the SMP process to explicitly consider the economic trade-off of different levels of environmental restrictions in SMPs, including no restriction, on a case by case basis. This economic trade-off should be the primary consideration of government in approving SMPs. In this respect, early consultation with government about the economic trade-off of different mine plans is important to avoid the business costs associated with lengthy approval times;
- Support from Government in sponsoring non-market economic valuation studies of different environmental outcomes to facilitate economic trade-off analysis;
- Improved communication to interest groups and the public of the of the expected, and Government accepted, subsidence impacts of underground mining and the fact that approved mining is expected to have some environmental impacts.

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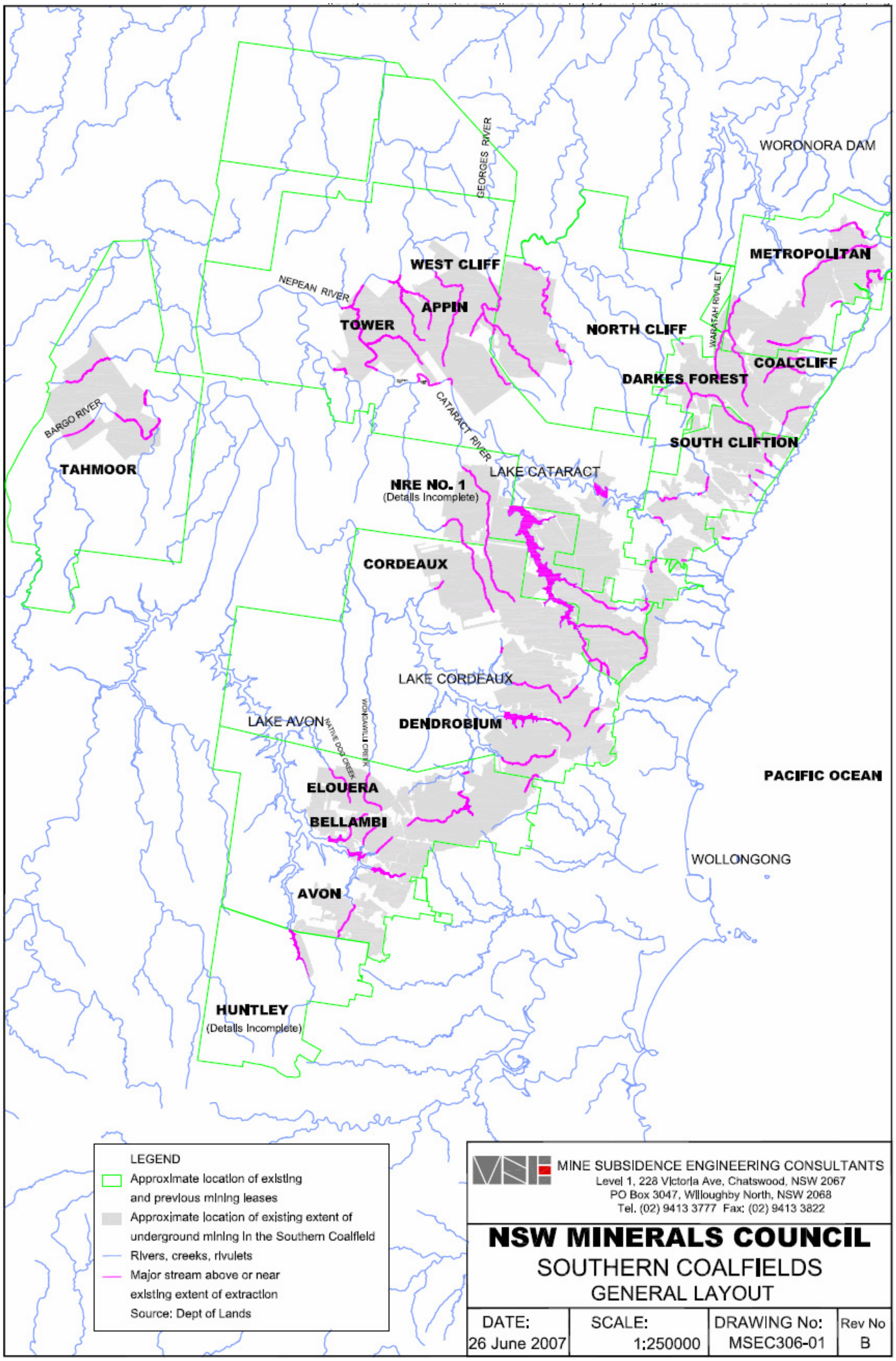
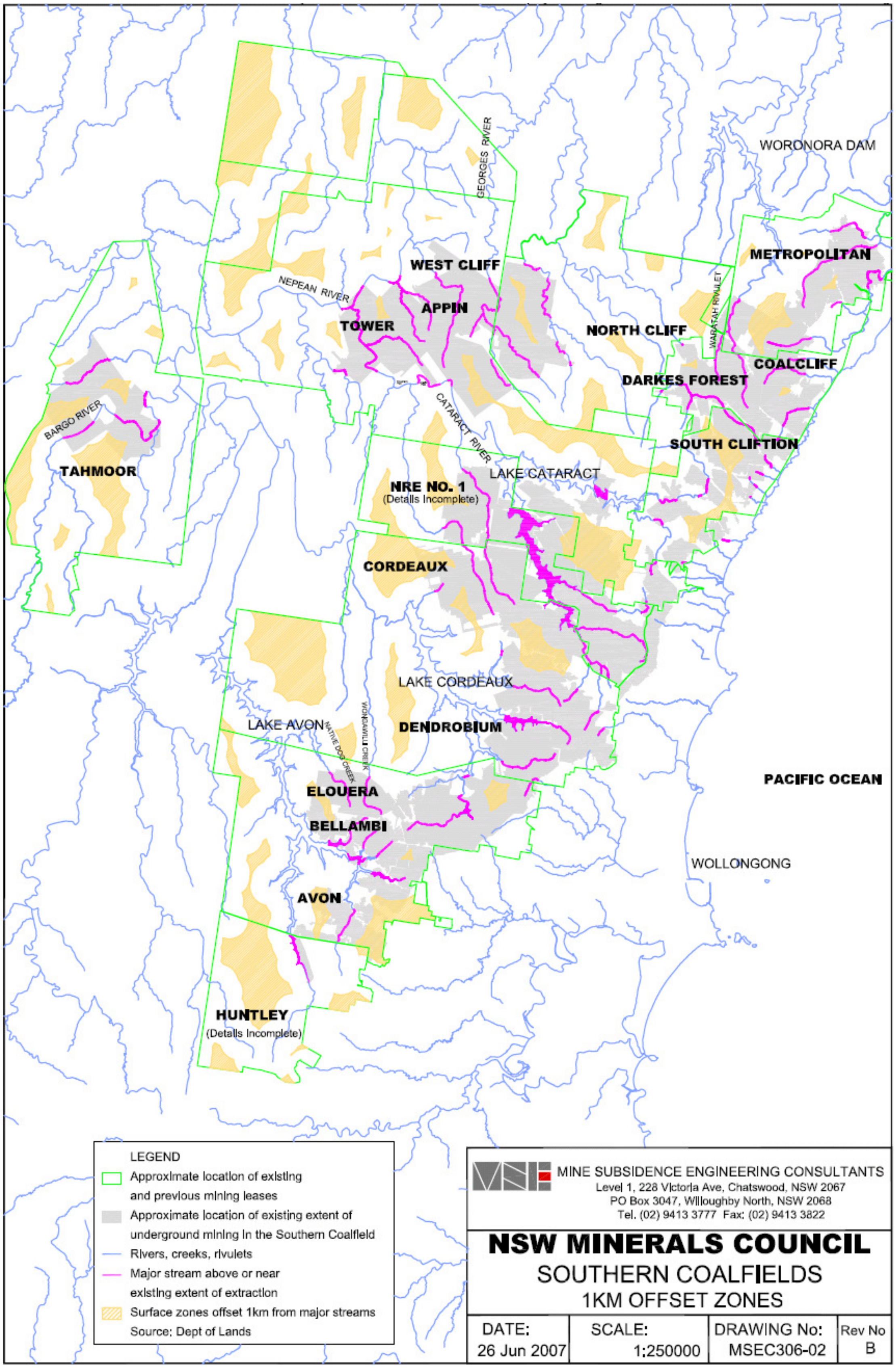
Appendix 1 – The approximate extent of underground mining in the Southern Coalfield



Appendix 2 – The effect of a 1km buffer zone on recoverable reserves



Appendix 3 – MSEC Report for NSWMC

Appendix 4 – Dr Noel Merrick Report for NSWMC

Appendix 5 – Biosis Research Report for NSWMC

Appendix 6 – Gillespie Economics Report for NSWMC