Application of the Coal Guidelines in reporting Coal Resources under the JORC Code

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Introduction

The basis of any coal mining operation is the Coal Resource, which forms the corner stone for Coal Reserves upon which mine planning and the extraction will be based. Without a correct understanding of the Coal Resource and importantly, the confidence in the estimate made, any Coal Reserve will be flawed and will likely lead to inappropriate mine design and failure to meet coal production and financial targets.

The approach by some 'Competent Persons' in the classification of Coal Resources under the 'Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves' (JORC Code) has been the unquestioned application of suggested distances around 'Points of Observation' in defining the confidence limits of classification. These suggested distances, as defined in the 'Australian Guidelines for Reporting of Inventory Coal, Coal Resources and Coal Reserves' (Coal Guidelines), have for some 'Competent Persons' become the de-facto standard when reporting. Often these distances are applied with little consideration of other factors. Not only are they applied to deposits within Australia, but also in recent years we now find that this distance-based method of estimating uncertainty and risk is being utilised for coal deposits internationally.

As a 'Competent Person' in estimating and classifying Coal Resources, who has had – in the span of my career – the opportunity to work on coal deposits located around the world, I challenge such an approach to Coal Resource classification.

The Coal Guidelines were developed over a period of some 40 years and played an important role in bringing some consistency to the reporting of Coal Resources and Reserves. It is important to understand this development, but also to understand the limitations of the distance-based approach to classification and the techniques that now provide better alternatives for classification of coal deposits in Australia and abroad.

History of the Coal Guidelines

In October of 1961 the 'Standing Committee on Coalfield Geology (SCCG) of New South Wales (NSW)' formed (Crouch A, 2001). Representation at that time was made by:

Government organisations, comprising the:

- Joint Coal Board of New South Wales (NSW)
- Geological Survey of NSW
- NSW Department of Mines.

Associations, including:

- Geological Society of Australia
- NSW Combined Collieries Proprietors Association.

Tertiary institutions represented by:

- University of Sydney
- University of NSW.

The mining industry supported by:

- BHP Ltd
- Australian Oil and Gas Corporation Ltd
- Australian Iron and Steel Pty Ltd.

It is noteworthy that at this time there was no Joint Ore Reserves Committee (JORC) – and consequently no JORC Code – yet reflection shows much of the SCCG's work could be credited in the founding of the JORC Code as we know it today.

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During the latter part of 1961 one of a number of topics drawn up by the SCCG included 'Suggested rules for calculating and reporting Coal Reserves in NSW'. The draft code for the calculation of Coal Reserves was a tentative document, with references to its being a 'guide' rather than a 'binding specification', with particular attention paid to the idea of distances between outcrops and bore holes being a 'desirable' feature of reporting, rather than 'mandatory' (Crouch A, 2001).

First edition of the Code

In 1971 Records of Geological Survey NSW published the first edition of 'Code for Calculating and Reporting Coal Reserves'. The salient points of this document were:

- confidence categories were defined for reporting of Coal Reserves
- definitions of terminology were made
- special considerations in estimating and reporting were given.

At this time four Coal Reserves categories were defined, under which coal could be estimated and reported. The term Resource didn't exist. Classification into one of the four Reserve categories was to be determined by 'objective appraisal'.

Measured Reserves

Measured Reserves had a density of observation points that was sufficient to give control on quality, thickness, depth and other relevant conditions. It would allow for a reliable estimate of the tonnage and the planning of its extraction. 'Experience at the time' showed that these conditions could rarely be met if the Points of Observation were spaced greater than 0.5 Mi apart. Often a greater density of points was required. Extensions beyond workings could be made to the Reserve where conditions were favourable. The maximum extension beyond the last point of observation (in the working) was 0.25 Mi.

Indicated Reserves

Indicated Reserves had a density sufficient for points of observation to allow a realistic estimate of the tonnage. There was an expectation that with increased information, the Reserve category classification could be raised to Measured. Generally the points of observation were spaced no greater than 1 Mi apart. Extensions beyond workings could be made to the Reserve where conditions were favourable. The maximum extension beyond the last point of observation (in the working) was 0.5 Mi.

Assumed Reserves

Assumed Reserves were defined from general geological conditions and sparse information. There was an expectation that with increased information the Reserve category classification could be raised. The term was intended for use within colliery holdings or an area the size of a holding. Generally the points of observation were spaced no greater than 2 Mi apart. There was a general assumption that continuity could be based upon geological inference.

Inferred Reserves

Inferred Reserves defined areas of poor cover of information with an uncertain estimate. There was an expectation that with increased information the Reserve category classification would be raised in part or all of the Reserve would be found not to exist. The term was intended for use within a coalfield or province. Estimates with this classification could only be reported within ranges:

- Very Large (> 10 billion tons)
- Large (100 million to 10 billion tons)
- Small (20 million to 100 million tons)
- Very Small (< 20 million tons).

Recoverable and Marketable Reserves

Definitions were provided for Recoverable and Marketable Reserves. Recoverable Reserves were defined as consisting of the tonnage of coal that can physically be mined from a Reserve at an acceptable cost, ie run-of-mine product. The term Recoverable could be used alone or in conjunction with the classification categories of Measured, Indicated and Assumed. Marketable Reserves consisted of the coal tonnage available for sale after marketing factors such as treatment were carried out.

Special considerations were documented as well. This included:

- Where coal was divided by major faults, dykes etc it was to be considered separate and reported as such.
- All factors used to limit Reserves and enable verification of calculations were to be explicitly stated.
- Overburden cover was considered to restrict reporting of Reserves if it exceeded 3000 ft.
- Seam thickness was considered to restrict reporting of Reserves were it was less than
- 3 ft.
- Coal quality parameters should be recorded with Reserves and reported within ranges.
- It could be assumed, in the absence of other coal density information, that one acre foot would contain 1700 long tons of coal.

Second edition of the Code

In 1974 a second edition of this Code was published. The four categories under which Coal Reserves could be estimated and reported remained the same, the main change being that the units of measurement were converted from imperial to the metric system.

Experience at the time showed that Measured Reserve categorisation conditions could rarely be met if the Points of Observation were spaced greater than 1 km. The maximum extension beyond the last point of observation (in the working) was 0.5 km.

Generally the points of observation were spaced for Indicated Reserves were no greater than 2 km apart. The maximum extension beyond the last point of observation (in the working) was 1 km with calculations taking known trends into account.

The points of observation for Assumed Reserves were generally spaced no greater than 4 km apart. There was an assumption that continuity could be based upon geological inference.

Inferred Reserves could still only be reported as a quantitative estimate within ranges:

- Very Large (> 10 billion tonnes)
- Large (100 million to 10 billion tons)
- Small (20 million to 100 million tons)
- Very Small (< 20 million tonnes).

Between the two publications the maximum distances for extrapolation increased, not by much, yet the affect could be appreciable, dependent upon placement of Points of Observation (Figure 1). In reality the change in distance was never meant to be that prescriptive, as was stated in the original Code, but rather a basic guide for extrapolation, as defined by the experience of the time.

Modifying factors used to limit Reserves as published in the 1974 edition were more clearly defined than in the 1971 version. A recovery factor of 70 per cent could be applied to the Reserve in the absence of a mining engineer and other advice. Other information that was required to be stated included:

- overburden limit
- thickness limits
- basis of coal quality testing.

Third edition of the Code

In 1978 a third edition of the Code was published. The SCCG took the step of removing Assumed Reserves from the Recoverable Reserves category. Recoverable Reserves could only be reported from the Measured and Indicated categories for possible underground mining and only from the Measured category for possible open cut mining.

Mining recovery factors were also modified from the previous 70 per cent default. A value of 60 per cent for underground mining and 90 per cent for open cut mining – in the absence of other information – was defined. In addition overburden limits for open cut mines were to be stated with overburden ratios expressed as volume of waste to tonnes of coal.

Fourth edition of the Code

Two years later a fourth edition of the Code was published. This edition included a pro-forma 'Public Statement of Coal Reserves', intended for use in public statements. Some mining company representatives were reportedly alarmed by the extent of the disclosure required by the public statement provisions, yet the SCCG's views were very much in line with the spirit of regulation that was abroad in the mining industry at that time (Crouch A, 2001).

Fifth edition of the Code

By 1986 a fifth edition was published, with definitions finally introduced for the terms 'Resources' along with 'Points of Observation', the later term having been used in prior publications yet not fully defined.

Coal Resources were defined as all of the potentially useable coal known, or assumed to exist, in a specific area from Points of Observation and from extrapolation based on these points.

Points of Observation were defined as intersection at a known location of coal bearing strata that provides information about the strata by one or more of the following methods:

- direct observation, measurement and testing
- observation, measurement and testing of bore core
- observation and testing of cuttings and use of downhole geophysical logs of non-cored boreholes.

Other definitions were also made, some for terms modified in usage from previous publications.

With Measured, Indicated, Assumed and Inferred Reserves now being referred to as Resources, additional information was placed around the definition of each. Although the maximum suggested distances did not change from the previous edition of the Code, the definitions did.

Inferred Resources were those for which there was limited information and as a result the assessment of this type of resource may be unreliable.

Assumed Resources were for which the Points of Observation were widely spaced but the geological conditions indicated that the coal seam(s) persisted between the points of observation. The Points of Observations should allow the presence of coal to be unambiguously determined and an estimate of the coal thickness to be made.

Indicated Resources were those for which the density and quality of Points of Observation was sufficient to allow for a realistic estimate of the depth, quality, and quantity of in-situ coal and for which there was reasonable expectation that the estimate of the resources would not vary significantly with more detailed exploration. Points of Observation should provide a level of confidence sufficient to enable conceptual planning of extraction and determination of the likely quality of the product coal.

Measured Resources were those for which the density and quality of Points of Observation was sufficient to allow for a reliable estimate of the coal thickness, quality, depth and in-situ tonnage.

Points of Observation should provide a level of confidence sufficient to allow for detailed planning and costing of extraction for specification of a marketable product.

Further rigour was placed around reporting with information pertaining to both Resources and Reserves stated on:

- each seam
- on a depth basis at regular increments
- on a seam thickness basis, with a minimum stated and separate tonnages for <1.5 m and >1.5 m
- where stone bands were greater than 0.3 m then seams should be reported separately
- on a quality basis, with seams with a raw coal ash of >35 per cent only included if an acceptable beneficiation and yield could be stated
- where significant variations due to heat affectation or oxidation occurred.

A coal density (of 1.4 g/cc) could only be applied – in the absence of other relative density information – to Assumed and Inferred Resources.

Coal Reserves were redefined as those parts of the Resource which were planned to be exploited and for which there was sufficient information to enable such planning. Reserves were categorised into three types:

- mineable *in-situ*
- recoverable
- marketable.

National edition of the Code

In April of the same year the Code was presented at the Government Geologists Conference and a month later published in a revised state in the Queensland Mining Journal, authored by the NSW Department of Mineral Resources and the Geological Survey of QLD. This version was also submitted to the Australian Minerals and Energy Council for consideration and adoption as the Australian Code. The revision dropped the Assumed Resource category, and elevated the Inferred Resource category; creating two subdivisions (Figure 2):

- Class 1 Inferred were the equivalent of the prior Assumed category
- Class 2 Inferred were the earlier Inferred category.

Three years later, in 1989, the 'Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves' was published by the JORC Committee. The JORC Committee had not considered the reporting of coal and appended to this publication the now national Code for Coal, recommending its adoption.

The Coalfield Geology Council of New South Wales

With the demise of the Joint Coal Board, the SCCG required a change in its constitution, as the Board was a referenced member. The SCCG saw an opportunity for a change in name also existed and in 1994 what is now known as the 'Coalfield Geology Council of New South Wales' (CGC) formed. The CGC immediately began work on yet another revision of the Code and a requirement that public statements for Coal Resources and Reserves be made by a 'Competent Person' (later called an 'Estimator') was introduced.

Guidelines for the Estimation and Reporting of Australian Black Coal Resources and Reserves

With a proposed revision also of the JORC Code, the CGC decided in 1998 to develop their Code into a set of guidelines for calculating Coal Resources and Reserves compliant with the JORC Code. In 1999 the CGC and Queensland Minerals Council (QMC) endorsed the 'Guidelines for the Estimation and Reporting of Australian Black Coal Resources and Reserves'. This was referenced in the 1999 JORC Code as a guidance document for reporting of Black Coal Resources and Reserves.

With this edition, introduction of reporting an expected error range (as a per cent) in both Measured and Indicated Resources was made. There were also expansions on existing definitions and new definitions provided, among these clarification was made that 'A Point of Observation' for Coal Quality was to have acceptable levels of recovery (normally >95 per cent), and the introduction of the term Exploration Results. The term 'Coal In situ' was also employed, enabling total 'in ground' coal inventory to be reported for government or internal company purposes.

The new guidelines went on to state that the distance based classification of Resources was defined as being 'broad' in nature and should be applied by the Estimator when determining categories under favourable geological conditions. In areas where seams are faulted, intruded, split, lenticular or subject to significant variations in thickness or quality, more closely spaced Points of Observation possibly supported by interpretive data will be required. It was also stated that the estimation procedure should be transparent and repeatable.

In 2001 the CGC and QMC published the second edition of the Guidelines, having the opinion it accommodated the wide variation of Australian Coal Deposits in terms of rank, quality and geological environment. They also recognised that the Estimator bore ultimate responsibility for the reported Coal Resources and Reserves.

Australian Guidelines for Reporting of Inventory Coal, Coal Resources and Coal Reserves

In 2003 the current edition of the 'Coal Guidelines' was published. Clarification was made in relation to the expected recovery around quality Points of Observation (>95 per cent linear recovery) and the suggested distance modified in relation to the Measured Resource category. This was reduced from 1 km to 500 m and 250 m at the data boundary. The other maximum suggested Resource category distances remained the same. This edition also suggested distances between Points of Observation may be extended if there is sufficient technical justification to do so, such as by geostatistical analysis, yet unfortunately neglected to say that there may be converse requirement to reduce distances.

Recent rumblings

Around mid-2009 the Australian mining industry was in the height of a boom cycle, with the thermal coal price moving from around $140 to $210/tonne in just under six months. This saw an influx of new players into the market attempting to bring projects on stream, and also some producers trying to increase production to exploit the new price index. At the same time there was an expectation of a revision to the JORC Code (updates were occurring approximately every five years). Neither a revision to the JORC Code or Coal Guidelines was forthcoming that year, yet disquiet was evident within the industry. Some 'Competent Persons' and some mining companies were voicing concern that the Coal Guidelines distances were being applied to coal deposits outside Australia and/or in a manner that was seen as 'cherry picking' the original intent and principles of the document.

By late 2011 a groundswell across eastern Australia's mining community existed, particularly with 'Competent Persons'/'Estimators' in regard to the application of the Coal Guidelines. A forum held at the CSIRO (Pinjarra Hills) premises showed opinion was mixed on whether or not the 'prescribed' distances contained with the Coal Guidelines should remain, particularly given that many were now applying geostatistical techniques to understand continuity between Points of Observation. It was evident that some mining companies took a more conservative approach to Coal Resource Classification than others (which they were entitled to do so), while others were definitely more bullish. Opinion was also voiced by some that some estimates seen in the public domain appeared to be incorrectly classified.

During late 2011, forums were held nationally to discuss proposed changes to the JORC Code. One such forum held jointly by The AusIMM and the Australian Institute of Geoscientists in Brisbane again raised the relevance of the Coal Guidelines in reference to its application in the estimation of Coal Resources.

In September 2012 an Exposure Draft revised JORC Code, with several significant improvements, was released for comment by industry.

Application of the Coal Guidelines with regard to the JORC Code 2004 Edition

It is yet to be seen what will transpire for the future of the Coal Guidelines, yet it is important to recognise that they do not override the provisions and intentions of the JORC Code for Public Reporting.

Clauses 37-39 of the JORC Code provide information that relates specifically to the Public Reporting of Coal Resources and Reserves. In summary these clauses imply the following:

- That clauses 1-36 including Figure 1 of the JORC Code apply.
- That Table 1 of the JORC Code should be considered persuasive when reporting both Coal Resources and Reserves.
- That for the purposes of Public Reporting, the requirements for coal are generally similar to those of other commodities and as such the term 'mineral' can be replaced by 'coal' and 'grade' by 'quality'.
- That for guidance on the estimation of Coal Resources and Reserves and statutory reporting not primarily intended for providing information to the investing public, practitioners are referred to the Coal Guidelines.

Abuses seen in application of the Coal Guidelines

Both the Coal Guidelines and the JORC Code (sections 21 and 22) provide clear definition that the Points of Observation must be sufficient for geological and/or quality continuity to be confirmed or assumed. Unfortunately, maximum classification distances, based on the Coal Guidelines, have sometimes been applied without any consideration of the evidence for geological continuity.

Single Points of Observation do not inform or enable an assumption of either geological and/or quality continuity in 'Measured' or 'Indicated' Coal Resources. Likewise, linear chains of Points of Observation do not enable either the physical characteristics, or shape, of a Coal Resource to be estimated in 3D space and therefore should not be used to estimate an 'Indicated' or 'Measured' Coal Resource.

Each seam/ply intersected within a borehole requires an individual assessment to determine whether or not a Point of Observation can be established. Treating an entire hole with the same level of confidence throughout can be completely incorrect, particularly where only partial sampling or non-representative recovery has been achieved. A lack of understanding of waste rock characteristics both in-seam and as overburden could also influence the confidence that can be assigned to the Resource.

The way in which both coal and waste are sampled and then tested can have a huge influence on the confidence assigned to the Resource. Irrespective of the distance between the points of observation, if the seam has not been properly sampled and tested for appropriate coal quality characteristics that enable the potential economic viability of the coal to be assessed, then the Competent Person should reflect this uncertainty in the classification of the Resource or Reserve and not fall back on the default maximum classification distances.

Alternatives to 'prescribed' distances

Australian coal deposits are becoming more challenging to mine and their complexity is far greater than those mined historically. Coal seams are deeper, thinner and structurally and chemically more complex. It is recognised that many deposits in other basins around the globe formed under vastly different depositional conditions to those experienced in eastern Australia.

The simplistic approach of using default distances around Points of Observations has now become out-dated and for some deposits other methods are clearly required to provide a more robust estimate and confidence in Coal Resource estimation.

Variograms have been used extensively in other Mineral Resource estimates for establishing continuity between samples. They are a recognised and accepted geostatistical technique for establishing the range of continuity for a variable of interest. Widely used in other sectors of the Minerals Industry, the variogram's application in Coal Resource estimation is appropriate, evidence-

based and increasingly popular. Like any estimation technique, variography requires a solid data foundation created through appropriate sampling and domain definition.

Many coal seams are recognised as having vertical zonation related to the depositional environment during formation. This vertical variability should be captured in the Coal Resource estimate through the modelling of domains and (if required) the definition of working sections where there is an impact on the economic potential of the seams.

Measured Resources are said to have a high level of confidence – what does this mean? The terms high, reasonable and low are subjective and alone they convey little information. The Competent Person should provide as much clarity around the uncertainties of the Resource estimate as possible so that risks and opportunities are better understood by those downstream of the estimation process.

The use of conditional simulation techniques to understand the expected variability in an estimate is also gathering increasing popularity. Case studies support such techniques which can clearly identify areas of higher risk and enable quantification of the variability that can be expected spatially. These techniques provide an opportunity for Coal Resource Estimators to use simulation to provide estimates of errors and confidence limits to the engineers developing the mine plans and Coal Reserve estimates. The SCCG considered this possibility and carried out research into the establishment of error at a particular confidence limit, although specific recommendations were not published in the Code.

Conclusion

As demonstrated by reviewing the history of the Coal Guidelines, 'Competent Persons' should not blindly apply a method for defining confidence levels that was based on local experience of the Hunter Valley and Illawarra Coal Measures, developed more than 40 years ago for defining the confidence of a Coal Resource estimate, particularly outside of these basins. Due consideration of the geology, sampling and coal quality testing data should always be at the forefront of Resource Classification and practitioners should take full advantage of the data analysis techniques that have developed and become readily available over the past four decades.

Categorisation of Coal Resource classification boundaries based solely based of a default distance of cored boreholes with associated coal quality analysis is not appropriate in many cases.

Importantly, improvement to Coal Resource classifications ultimately leads to reduction in risk for the coal company and for investors. Poor classification translates to missed opportunities and lost profits.

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