COAL EXPLORATION AND GEOSTATISTICS

Moving from the 2003 Guidelines to the 2014 Guidelines for the Estimation and Classification of Coal Resources
1 INTRODUCTION

Coal exploration typically starts with field reconnaissance surveys and outcrop mapping. This is regularly followed up with some form of aerial survey, particularly a topographic survey. The popular topographic survey method is airborne, most commonly adopting the LiDAR (laser) technique.

Once we have established the presence of coal, the next step is to determine the extent and continuity of the coal seam(s). This is best done through exploration drilling, although there are other methods and techniques like 2D and 3D seismics and other non-invasive methods.

Geostatistics in Coal Exploration is a relatively new development although it has been around in precious and base metal exploration for a long time. It is gaining popularity globally and this is very much a direct result of the recently (2014) released ‘Australian Guidelines for the Estimation and Classification of Coal Resources’. These guidelines are the update and replacement of the classic 2003 ‘Australian Guidelines for Estimating and Reporting of Inventory Coal, Coal Resources and Coal Reserves’.

2 EXPLORATION DRILLING

The basic concept underpinning coal exploration drilling is the size and shape of the drilling grid. Since most coal seams are relatively flat lying (dips generally less than 20°), coal is typically best modelled in a 2D grid-based system, and thus the Points of Observation (drill holes) that are used to interpolate a regular grid are often set out on a regular grid.

Drilling grid patterns vary but are commonly square/rectangular or rhombic/triangular. Figure 2.1 shows these grid patterns.

![Figure 2.1 Comparison of areal coverage obtained with either the Square Grid or Triangle Grid patterns](image)

The figure above also shows how the two patterns influence the areal coverage obtained with a fixed number of drill holes. The 2003 Guidelines have heavily influenced how patterns are prepared depending on the desired outcome expected from the exploration. Drill hole
positions are often placed on a grid with spacing equal to the required JORC Confidence Category. Drill patterns should firstly take into account the interpreted underlying geology and structural domains, and then only as a function of continuity confidence and JORC Classification Categories.

3 **THE 2003 GUIDELINES**

The 2003 Guidelines have long been used by coal resource geologists and estimators to classify Coal Resources in terms of the JORC confidence categories: Measured, Indicated, and Inferred. The classification is presented in the 2003 Guidelines as a function of drill hole spacing. Below are some key excerpts from the 2003 Guidelines.

3.1 **POINTS OF OBSERVATION**

“Coal Resources can only be estimated from data obtained from Points of Observation. Interpretive Data are not Points of Observation but may increase confidence in the continuity of seams between Points of Observation.”

3.2 **INFERRED RESOURCES**

“Inferred Coal Resources may be estimated using data obtained from Points of Observation up to 4 kilometres apart. Trends in coal thickness and quality should not be unreasonably extrapolated beyond the last line of Points of Observation. ‘Extrapolated’ refers to the distance the estimate is extended past the last line of Points of Observation into areas for which no data are available.”

3.3 **INDICATED RESOURCES**

“Indicated Coal Resources may be estimated using data obtained from Points of Observation normally less than 1 kilometre apart, but the distance may be extended if there is sufficient technical justification to do so; for example, if supported by geostatistical analysis. Trends in coal thickness and quality should not be extrapolated more than half the distance between Points of Observation.”

3.4 **MEASURED RESOURCES**

“Measured Coal Resources may be estimated using data obtained from Points of Observation normally less than 500 metres apart, but the distance may be extended if there is sufficient technical justification to do so; for example, if supported by geostatistical analysis. Trends in coal thickness and quality should not be extrapolated more than half the distance between Points of Observation.”

3.5 **IMPACT OF THE 2003 GUIDELINES ON EXPLORATION DRILLING**

The single biggest and most devastating impact the 2003 Guidelines have had on Coal Exploration is that drill grids are designed to meet the JORC Confidence Category spacing recommendations rather than to address structural and coal quality issues. Structural and coal quality continuity are interpreted at various levels of confidence as a function of the drill spacing and the spacing : confidence relationship is variable depending on the coal seam
geology and structural complexity. In other words, 500 m spacing for Measured in one coalfield does not necessarily apply in another coalfield.

However, this key component of resource evaluation has gone unchecked and confidence categories are blindly assigned based exclusively on drill hole spacing.

3.6 **FAILURE OF THE 2003 GUIDELINES**

The 2003 Guidelines became the preeminent reference and methodology for classifying Coal Resources. The failure has been that geologists and estimators failed to fully examine the exploration data and resultant interpretations leading to poorly classified resources in terms of confidence categories.

The best example of this failure is the classic “Spotted Dog” Resource Classification Plan often seen in technical reports.

Figure 3.1 is one such example.

![Figure 3.1: Classic Spotted Dog Resource Classification](http://www.ausimm.com.au/content/docs/spotted_dog_paper.pdf)

Typically, resources in each category were over-estimated, with the net result being a global over-estimation of Coal Resources. This is obviously not ideal.

Other geologists and estimators attempt to smooth the spotted dog effect by firstly considering only holes in close enough proximity that their respective “areas/circles of influence” overlap and that no less than three points of observation must overlap before an area is considered. Figure 3.2 is an example of this modified concept.
Nonetheless, Coal Resource Classification methodology has been not been addressed in public reporting for quite some time although it has been the focus of intense internal debate amongst geologists and estimators for quite a while.

The drill hole spacing methodology is based on real exploration examples and is not without merit. What the methodology lacks is a basis for defining the spacing in a variety of different geologic and geotechnical environments. In other words, a 500 m spacing may prove to satisfy the *Measured* confidence test in a geologically simple and undisturbed coalfield such as the Morupule Coalfield in Botswana (southern Africa). Historical exploration and current mining has shown that the coal seams are persistent in elevation, thickness and quality over distances up to 2,000 m!

However, a 500 m drill hole spacing in coalfields that are structurally complex, like parts of the Moatize Basin in Mozambique, is by far too great to allow confident interpretation of continuity.

The 2003 Guidelines became a fall-back for geologists and estimators and allowed Coal Resources to be classified on drill hole spacing alone. This is not ideal.

4 **The 2014 Guidelines**

To address the issue of poorly classified Coal Resources, various experts and specialists convened a committee to effectively rewrite the 2003 Guidelines. In late 2014, the Guidelines Review Committee released, on behalf of the Coalfields Geology Council of New South Wales and the Queensland Resources Council, the 2014 Edition of the Australian Guidelines for the Estimation and Classification of Coal Resources.

The first noticeable difference is the title of the guideline. It has changed from *Estimating and Reporting* to *Estimation and Classification*, and the 2014 Guidelines only refer to Coal...
**Resources** while the 2003 Guidelines refer to *Inventory Coal, Coal Resources and Coal Reserves*. This is a significant development in that the 2012 Edition of the JORC Code refers to the 2003 Guidelines or its successor document and the 2014 Guidelines is the successor document. Thus, the guidelines referred to in the JORC Code are now relevant to Coal Resources ONLY.

The second and most important change in the 2014 Guidelines is the removal of the recommended maximum spacings for the JORC Classification Categories. Now it is up to the Competent Person to justify the Confidence Category assigned to a Coal Resource.

The 2014 Guidelines promotes, among other methods, the use of GEOSTATISTICS to assist the Competent Person in this task.

Perhaps the single biggest contribution to Coal Resource Classification that geostats brings is the concept of spatial correlation. The semi-variogram is the tool that defines the limits of spatial correlation and therefore can be used as a guide to the spacings between points of observation when determining JORC Confidence Categories.

Not only does geostats contribute to spatial correlation assessments, it feeds into the actual modelling of the physical and coal quality parameters. Typically we use an Inverse Distance (weighted), IDW, linear estimator for coal modelling. With geostats, we can now interpolate using a kriging estimator (Ordinary Kriging, OK) and the semi-variogram. The Kriging Variance can be determined and this is a measure of spatial correlation and thus confidence in continuity.

By way of example, Figure 4.1 is a parameter modelled using the IDW estimator. Figure 4.2 is the same parameter modelled using OK based on a semi-variogram of the data. Once can see that although the general “look and feel” of the plots is similar, the OK-modelled data set appears to highlight the data trends much better.

![Figure 4.1 IDW modelled seam thickness](image-url)
Figure 4.2  OK modelled seam thickness

Figure 4.3 is the Kriging Variance. Warm (red) regions denote a poor spatial correlation (Inferred Resources), while the cooler (blue) regions show better spatial correlation (Measured Resources).
5 CONCLUDING REMARKS

While the basic concept underpinning coal exploration will remain drilling holes, our drill hole planning and data assessment needs to adapt to take into account an understanding of the concept of spatial relationships and continuity.

It is no longer good enough, or acceptable, to simply refer to drill hole spacing and grid dimensions as a basis for defining JORC Classification Categories. The Competent Person will have to JUSTIFY the category definitions in the public (JORC) report!