LOCATING DRILL HOLES TO REDUCE MULTIVARIATE RISK

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ABSTRACT

Exploration drilling for resource/reserve definition is commonly carried out on regular patterns, related to resource classification goals, budget constraints, and geological interpretations. Subsequent infill drilling may be required to achieve resource/reserve goals. It is during the latter infill drilling phase that an opportunity exists to target the drilling in areas that will contribute more to the reduction of project risk. For coal projects, risk could involve numerous factors including seam thickness uncertainty, parting thickness uncertainty, and failure to meet predicted product specifications.

A methodology for locating drill holes that reduces multivariate risk is described and demonstrated for a structurally complex coal deposit with particularly variable coal quality. Proposed drill hole locations are ordered on priority, thus, budget constraints can easily be accounted for by rank and cut methods.

INTRODUCTION

Development of a coal resource potentially amenable to underground mining, located to the north of the existing Huntly East colliery is currently being evaluated by Solid Energy New Zealand Limited (SENZ). The Huntly North project is situated immediately to the north of the Huntly East colliery in the Waikato coalfield of the North Island of New Zealand. The mine takes its name from the nearby town of Huntly, which has been one of the major coal mining centres in New Zealand for many years. The mine is one of several opencast and underground mines operated by SENZ, supplying coal to both export and domestic markets.

The principal seams of economic interest in the area of the proposed mine are the Renown (RM) and Kupakupa (KK) Seams. Both seams are subdivided into two distinct horizons by a non-coal partings. The RM and KK Seams at Huntly North may coalesce to essentially form a single mining horizon or occur as two distinct coal seams separated by a non-coal parting that varies markedly in thickness across the project area. The seam and parting thicknesses and coal quality have been sampled by 53 relatively sparse diamond drill holes within the project area. An additional 100 diamond drill holes, that provide short-scale seam thickness and quality information, were available immediately to the south of the study area.

A conditional simulation study involved assessing the impact of varying the exploration sampling patterns on the seam (parting) thickness and coal quality estimation errors. The sampling patterns investigated varied from 25 by 25m to 250 by 250m, selected to cover the spectrum from very closely spaced to sparse coal seam information. In economic terms, these spacings varied from prohibitively costly to potentially providing insufficient information to make reasonably informed mining decision.

The conditional simulation study indicated that systematic overestimation of the parting thickness would be common close to where the Renown and Kupakupa Seams coalesce for drill hole spacings greater than 50 by 50m. This region is important for mine planning purposes as it is envisaged that the RM Seam will be sterilised whenever the non-coal parting exceeds 0.25m. The probability of incorrect mine planning decisions was shown to often exceed 20% close to where the RM and KK seams coalesce. Furthermore, potentially high ash and sulphur coal that would either be left *in situ* or require suitable blending practices to meet product specifications also required identification. Significantly, higher uncertainty/risk areas for each attribute of interest were commonly spatially separate.

To account for multivariate risk a novel approach to identifying potential drill hole locations for subsequent sampling and that simultaneously considers the risk of all attributes was adopted.

METHODOLOGY AND IMPLEMENTATION

The methodology employed is based on the quantification of uncertainty/risk as established by 100 simulations of seam/parting thickness, and sulphur and ash content. In this study:

$$\mathit{Uncertainty} = \mathit{variance}$$

$$\mathit{Risk} = \begin{cases} q(c) & \text{if } q(c) \le 0.5 \\ 1 - q(c) & \text{if } q(c) > 0.5 \end{cases}$$

where $q(c)$ is the quantile corresponding the attributes cut-off value, and measures the proportion of the simulated values that are below the cut-off. A quantile value of 1.0 corresponds to 100% probability that the simulated outcomes for a location are below the cut-off value, and a quantile value of 0.0 corresponds to 100% probability that the simulated outcomes for a location are above the cut-off value. Quantile values between 0.0 and 1.0 indicate that some simulated values were above the cut-off value and some simulated values were below the cut-off value. In other words, risk > 0 only when part of the simulated distribution is above the cut-off value and part of the simulated distribution is below the cut-off value. Note that, the maximum individual risk value is 0.5 as risk is effectively measured as the closest distance from an extreme quantile (0.0 or 1.0) to the measured quantile.

The algorithm employed to determine potential drill hole locations was:

1. Define a set of blocks based on a specified drill hole spacing.
2. Calculate the average uncertainty/risk in each block.

Then for each drill hole location required,

3. Select the block with the highest remaining uncertainty/risk.
4. Identify the drill hole location as the point within the current block from step (3) that has the highest uncertainty/risk.
5. Remove the current block from further consideration.
6. Go to step (3)

The following parameters were used:

- thickness is an aggregate where the KK-RM parting is <0.25m, calculated as
  - *thickness* = *KK thickness* - if parting ≥0.25m
  - *thickness* = *KK* + *parting* + *RM thickness* - if parting <0.25m;
- thickness cut-off for coal resource = 8m;
- large zones of coal with sulphur content >0.35% in will be left *in-situ*, i.e. the sulphur cut-off is 0.35%;
- large zones of coal with ash content >8.0% will be left *in-situ*, i.e. the ash cut-off is 8.0%;
- number of drill holes required = 30; and
- minimum distance between drill holes = 150m.

The following scenarios were investigated:

1. resource volume uncertainty (variance);
2. parting risk – related to the 0.25m parting cut-off;
3. thickness risk – related to 8m thickness cut-off;
4. sulphur risk – related to the 0.35% sulphur cut-off;
5. ash risk - related to the 8.0% ash cut-off;
6. total risk - equal weightings applied to parting, thickness, sulphur, and ash risk; and
7. combined resource volume uncertainty (50% weighting) and total risk (50% weighting).

Figure 1 shows the local uncertainty/risk values (standardised to 1) and the corresponding 30 drill hole locations. Note that:

- as only 30 drill hole locations were specified large areas of the study area may not contain a drill hole;
- as expected, drill holes are strongly correlated with high uncertainty/risk values. The exception being for ash risk, where drill holes were positioned in randomly selected blocks once all blocks with risk values greater than zero were considered; and
- some "edge effects" can be noted in plots due to the lack of data in these regions, especially in the northern areas. It is expected that the final decision for drilling in these areas would be reviewed based on all available information.

The approach adopted herein assumes that each of the four parameters considered (parting thickness, seam thickness, sulphur and ash contents) are of equal importance in determining whether a particular parcel of coal should be mined. This function may be varied to place relatively greater or lesser emphasis on a single parameter in order to modify the risk profile on which recommended drill hole locations are ultimately based. Assigning equal weights to the four parameters listed is considered by the authors to be a reasonable assumption for feasibility purposes, where establishing confidence in global resources is the principal consideration. This may not, however, be the case in production situations where infill drilling or sampling may be required to help ensure coal in a particular mining panel meets specific customer specifications, and additional sampling is required to reduce the potential for error in a specific parameter to an acceptable level. This situation is more likely to apply to coal quality rather than parameters describing the volume of coal present and amenable to mining.

The same approach may also be used to assess the extent to which drilling recommendations are sensitive to the values of specific parameters. This would be expected to reflect the continuity of the parameter within the area being investigated.

CONCLUSIONS

A methodology for locating drill holes to reduce multivariate risk was proposed and demonstrated for a structurally complex coal deposit in New Zealand. Local multivariate risk values were calculated as a weighted linear combination of individual local risk values. Then, optimal drill hole locations were selected by considering spatial locations ordered by decreasing multivariate risk taking into account a minimum acceptable spacing.

Whilst the proposed methodology considers explicitly multivariate risk, there is no guarantee that the acquisition of sample data at the identified locations will reduce the potential for error for a specific attribute to an acceptable level.

Other mitigating factors, such as access, mine design, structure, and geotechnical data acquisition, were also considered in determining the final drilling locations for the Huntly North project.

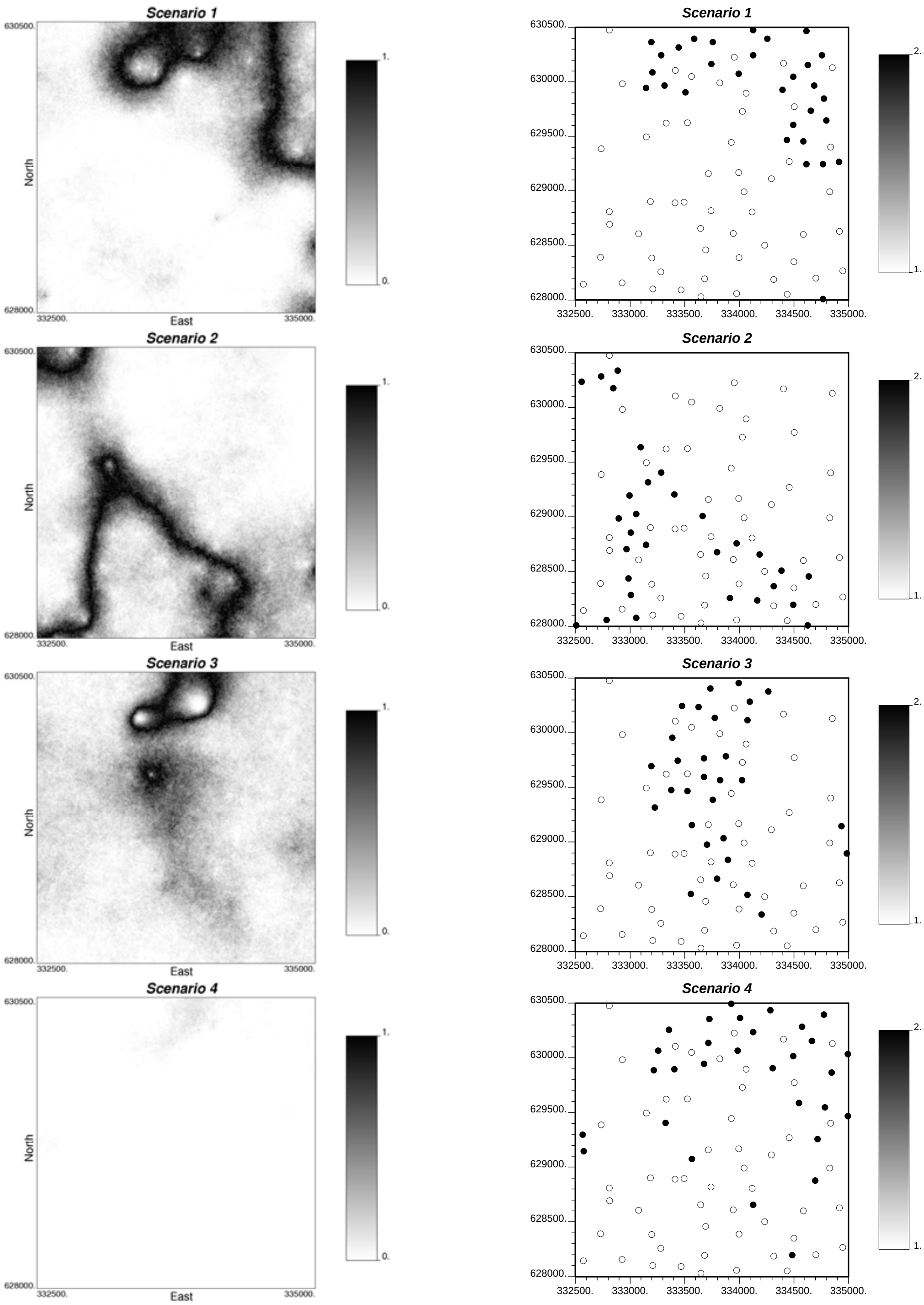

Figure 1 Risk maps and drill hole locations.

(Note: white = current drill hole; black = proposed drill hole)

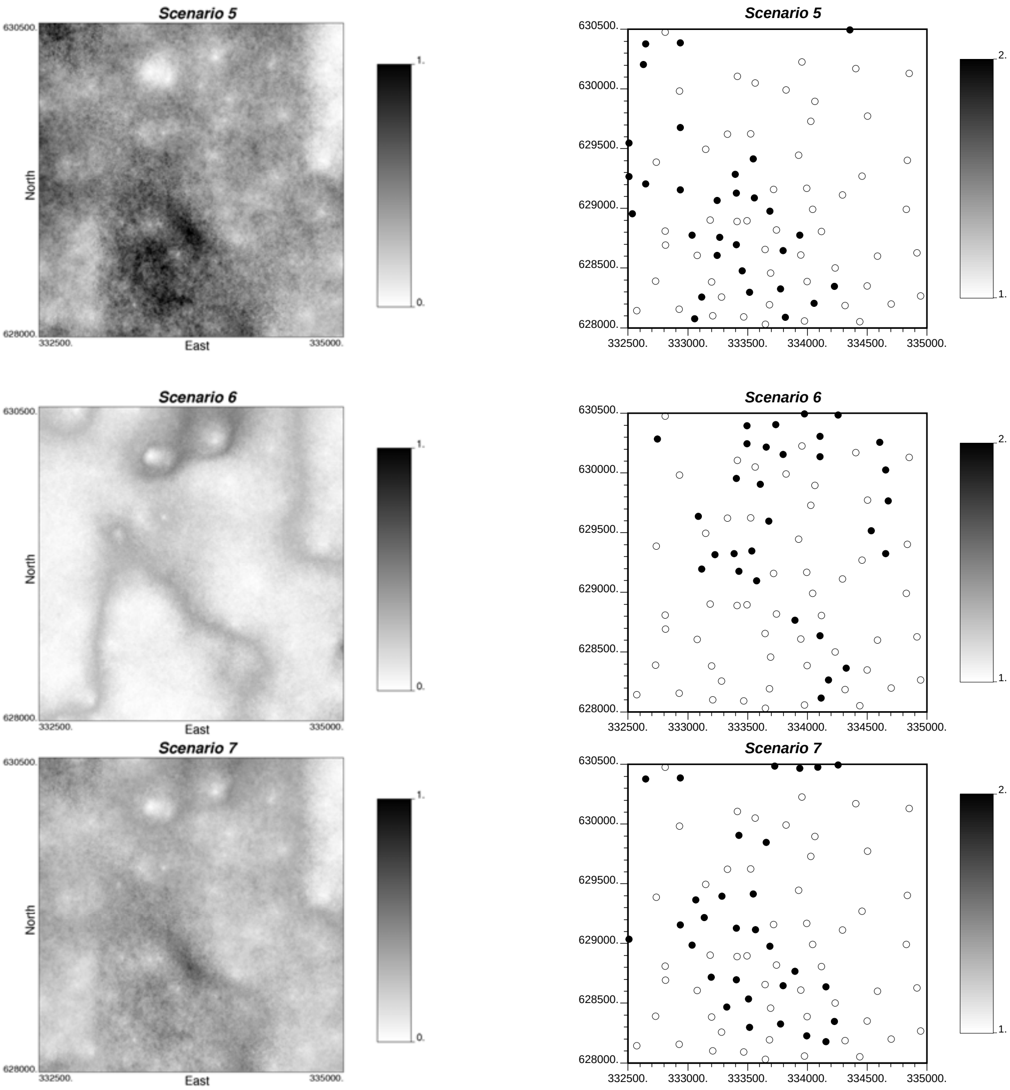

Figure 1 continued Risk maps and drill hole locations.

(Note: white = current drill hole; black = proposed drill hole)