Estimation of Inherent Boundary Dilution in Regularised Block Models

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Summary

Modern resource estimation techniques utilise block models to facilitate geostatistical analysis and distribution of grade estimates. Interpolation of grades into cells are typically constrained by wire frames of the deposit boundaries defined by drill hole logging, sampling and mapping of the deposit. Block models being orthogonal cuboids, based on a north south, east west grid only approximate the wireframe boundary. While large block models with many cells are likely to reconcile well with total volumes local variations will occur. To improve local estimates from boundary effects smaller cells sizes are typically used. The smaller cells (Sub cells) are assigned the same grades as the parent cell. The sub cells reduce the scale of the error in deposit boundary estimation however inaccuracies remain and dilution from waste cells or low grade mineralisation occurs. Reconciliation of block model volume against the wireframe volume provides an insight in the volume variance however, the inherent loss and dilution within the model is not apparent. This paper discusses some reasons for inaccuracies and presents a simple approach to estimation of the inherent dilution of ore grades in block models.

Introduction

Modern resource estimation techniques utilise block models to facilitate geostatistical analysis and distribution of grade estimates. Interpolation of grades into cells are typically constrained by wire frames of the deposit boundaries defined by drill hole logging, sampling and mapping of the deposit. Block models being orthogonal cuboids, based on a north south, east west grid only approximate the wireframe boundary. While large block models with many cells are likely to reconcile well with total volumes local variations will occur. To improve local estimates from boundary effects smaller cells sizes are typically used. The smaller cells (Sub cells) are assigned the same grades as the parent cell. The sub cells reduce the scale of the error in deposit boundary estimation however inaccuracies remain and dilution from waste cells or low grade mineralisation occurs. Reconciliation of block model volume against the wireframe volume provides an insight in the volume variance however, the inherent loss and dilution within the model is not apparent. This paper presents a simple approach to estimation of the inherent dilution of ore grades in block models.

AusIMM JORC Code - 2012 Edition.

The AusIMM, JORC code, 2012 edition, requires that a Reserve Estimate be supported by a Prefeasibility level study. Mining Recovery and Mining Dilution modifying factors need to be supported by reasonable assumptions.
Many variables need to be considered in the estimation of Mining Recovery and Mining Dilution. - Ref Mining Recovery and Dilution, KBPL 2013.

To quantify the likely dilution from mining activities it is first necessary to understand the dilution inherent in the block models used to estimate the Mineral Resources and regularised models used to estimate Ore Reserves.

Geological interpretation of drill hole logging and sampling is used to create a 3 dimensional shape of the deposit which is a triangulated surface called a wireframe. This shape is considered to be the best description of the deposit location, geometry and volume.

There is current misconception in the industry that it is always necessary to add dilution to resource estimates. There are many examples of mining operations that report a positive reconciliation between the resource, reserve and grade control models. These cases could be a result of underestimation of the resource or too high inherent dilution in the block model.

Block Model Boundary Approximations

Block model cells are created relative an origin point. This point determines the location of the cell centroids shown in Figure 1 below. Wire frames of interpreted geological boundaries are also shown as blue lines. Ore is typically defined as those cells whose centroid falls within the wireframe boundaries. The relative location of the centroid to the boundary is therefore very important as it will determine what is flagged as ore and waste.

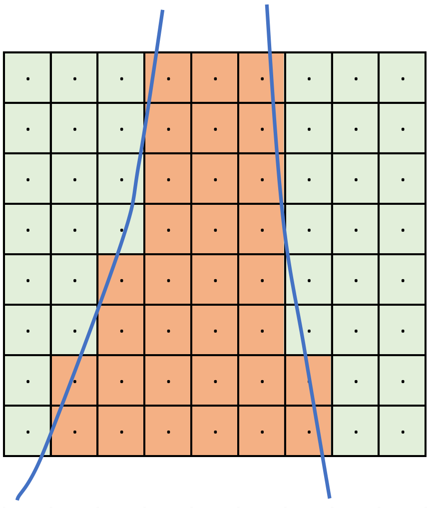

Figure 1 Section through a Block Model

It can be seen in Figure 2 that the blocks only approximate the wireframe boundaries and there is material, shaded red that within the wireframe boundary that has not been included in the block model ore volume, and material outside wire frame that is included in the block model ore volume.

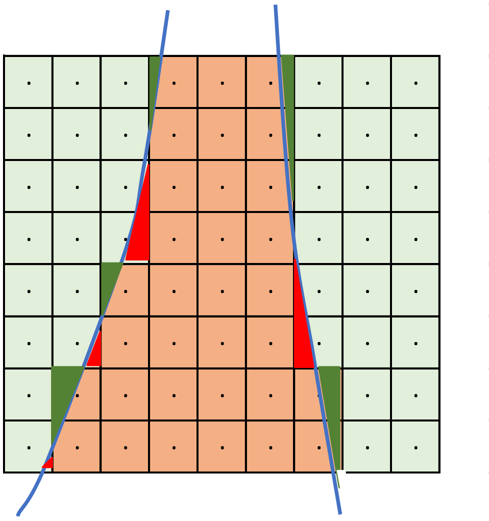

Figure 2 Material included and excluded from Block Model volumes

The material not included in the block estimate can be considered to be a loss of ore and the material outside the wire frame but included in the block model volumes a dilution. It can be seen that local variations occur and there is no reason for the local loss to be compensated by the local dilution, moreover as the grades of the cells are different the grade dilution cannot be estimated by a simple reconciliation between the wire frame and the block model total volumes.

Cell Centroid Relative to Wireframe Boundary

The location a cell centroid relative to the deposit boundary will determine the inherent dilution within the cellular estimate of the wireframe volume.
It can be assumed there are sufficient blocks relative to boundaries for the total ore cell volume to equal the wireframe volume.
For a regularised model with the following cell dimensions:

- 10m in X direction
- 10m in Y direction
- 10m in Z direction

Then:

- The angle of the Dip determines the thickness of the wedge of loss or dilution
- Maximum wedge thickness is 0.5 the cell width
- The mean wedge thickness is likely to be 25% of the cell width assuming many cells are calculated.

Assuming for every boundary block where dilution occurs there is an equivalent boundary block where loss occurs then only 50% of the boundary blocks will be subject to dilution. Further for a tabular ore deposit the dilution will occur on both hanging wall and foot wall boundaries.

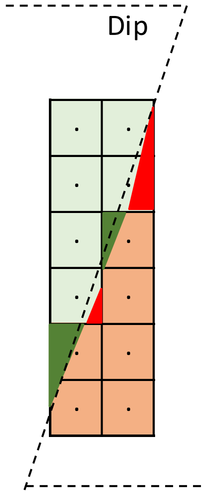

Figure 3 Section View showing balanced loss and dilution down dip

Similarly along strike it can be assumed that loss and dilution is determined by the cell grid orientation relative to the strike of the deposit.

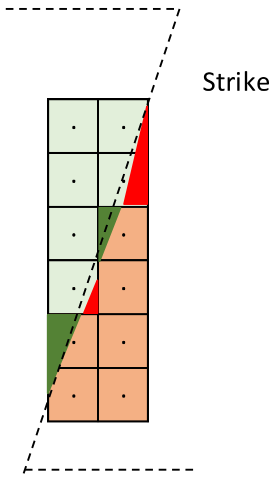

Figure 4 Plan view showing balanced loss and dilution along strike

The volume of diluent material in the cellular model is therefore, 25% X cell dimension * 25% Y cell dimension *25% Z cell dimension* 0.5 * 2.0. For example of a 10m X 10m X 10m cell the inherent dilution due to centroid and boundary variation is 1.56% of the cell volume.

Cell Grid Orientation to Deposit Dip and Strike Directions

To calculate the dilution due to deposit geometry the apparent width of the deposit is calculated from the dip of the deposit. The apparent X and Y widths and lengths are used to find the fractional cell count required to account for the dip and strike effects over a portion of the deposit. The fractional block count is then divided into the whole block count to determine the dilution in the set of blocks that cover the dip and strike extensions. It can be seen from Figures 5 and Figure 6 that the slight misalignment of strike to the cell grid results in significant inherent dilution.

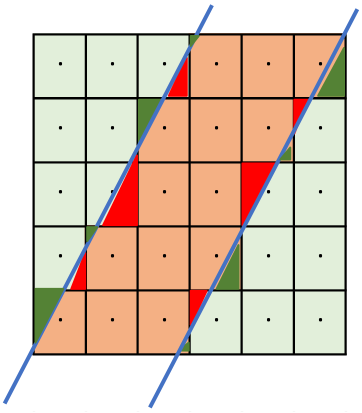

Figure 5 Sectional View of cells showing dilution resulting from the Dip of the deposit

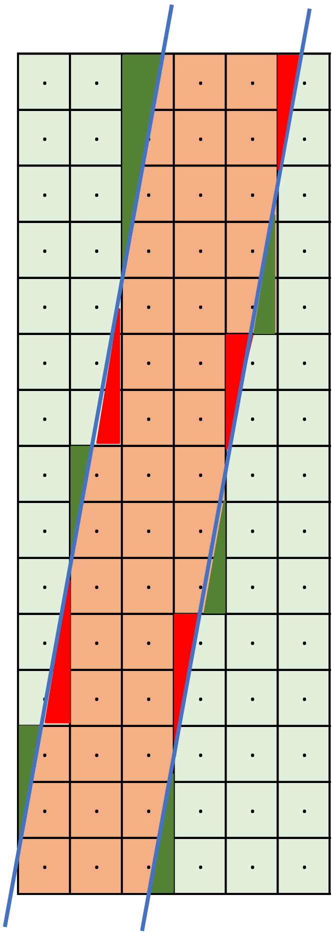

Figure 6 Plan View of cells showing dilution resulting from the strike of the deposit relative to the Block Model Grid

Mineral Resource Under Reporting Due to Cell Size

The following example calculation demonstrates the impact of changing cell size on the inherent cell dilution. In the case of Lens A reducing the block size results in 3% less inherent dilution as a result of there being less total volume in the small cell whole block volumes.

Lens B has a relatively narrow true width of 5m compared to the cell size of 10 x 10 x 12. This has resulted in only 52% of the cells having centroids within the Lens B wire frame, resulting in considerable under reporting of Mineral Resource. By reducing the cell size to 5 X 5 X 6 the likelihood of the cell centroid falling within the wireframe has increased significantly. The reduced cell size has improved the dilution caused by boundary variation to the centroid by 1 % however the inherent dilution due to the relative dip and strike to the block model grid remains unchanged as whole cell dimensions are by chance the same as the fractional volumes.

Estimates of Block Model Boundary Dilution

A regularised block model will have inherent loss and dilution that will vary significantly with only minor changes to the cell centroid, orientation and size.

Simply increasing the size of regularised blocks to a size proposed to be a SMU will not quantify Mining Recovery and Mining Dilution.

KBPL has developed a spreadsheet model that can be used as a quick check of boundary dilution when selecting block model cell sizes and orientation.

Before Mining Recovery and Mining Dilution factors are estimated it is recommended that the inherent boundary dilution in regularised block models is quantified. This can then be used in conjunction with the proposed grade control procedures and systems. Ref KBPL Mining Recovery and Dilution 2013.

Understanding the inherent block model boundary dilution is an important first step for estimating Mining Recovery and Mining Dilution Modifying Factors for JORC Code Reserve Estimates.

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Example Calculation

		Lens A	Lens A	Lens B	Lens B
True width	m	25	25	5	5
Dip	degrees	65	65	65	65
Strike	degrees	170	170	170	170
Strike angle to grid (max 45)	degrees	10	10	10	10
Percentage of total deposit		75%	75%	25%	25%
Regularised cell size					
X	m	10	5	10	5
Y	m	10	5	10	5
Z	m	12	6	12	6
Dilution of ore cells due to boundary cell variance to centroid					
Mean boundary variance to centroids		0.25	0.25	0.25	0.25
X	m	9.1%	4.5%	45.3%	22.7%
Y	m	1.7%	0.9%	8.7%	4.3%
Z	m	5.1%	2.5%	25.4%	12.7%
Boundary variance dilution		0.0%	0.0%	1.0%	0.1%
Likelihood of cell centroid within wireframe					
X		275.8%	551.7%	55.2%	110.3%
Y		1439.7%	2879.4%	287.9%	575.9%
Z		493.0%	985.9%	98.6%	197.2%
Likelihood of cells flagged as ore		always	always	55.2%	always
Dilution due to lens geometry					
Ore Dimensions					
X	m	27.6	27.6	5.5	5.5
Y	m	144.0	144.0	28.8	28.8
Z	m	59.2	59.2	11.8	11.8
Volume of cell ore	m^3	234923.2	234923.2	1879.4	1879.4
Fractional cells containing deposit geometry					
X	cells	2.8	5.5	0.6	1.1
Y	cells	14.4	28.8	2.9	5.8
Z	cells	4.9	9.9	1.0	2.0
Whole cells containing deposit geometry					
X	cells	3.0	6.0	1.0	2.0
Y	cells	15.0	29.0	3.0	6.0
Z	cells	5.0	10.0	1.0	2.0
Whole cell dimensions containing deposit geometry					
X	m	30.0	30.0	10.0	10.0
Y	m	150.0	145.0	30.0	30.0
Z	m	60.0	60.0	12.0	12.0
Cell Volumes	m^3	270000.0	261000.0	3600.0	3600.0
Volume of inherent cell dilution	m^3	35076.8	26076.8	1720.6	1720.6
Inherent lens geometry dilution		**13.0%**	**10.0%**	**47.8%**	**47.8%**
Total Inherent Cell Dilution		**13.0%**	**10.0%**	**48.8%**	**47.9%**