# The Checkerboard Effect and Mineral Resource Reporting for Underground Mines

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# Agenda

- Introduction
- Review of Concepts
- Possible/Suggested Solutions
- Wrap Up

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- All discussions and opinions presented in this presentation are those of the authors only.

# Introduction

- A fundamental requirement of the CIM Definition Standards for reporting of Mineral Resources is that the “Reasonable Prospects for Eventual Economic Extraction” (RPEEE) must be met.
- The key point of this presentation is that the Mineral Resource practitioner must consider the selectivity of the potential underground mining method in relation to the spatial configuration of blocks below cut-off grade to blocks above cut-off grade when preparing a Mineral Resource statement – “the checkerboard effect”.
- Several examples will be presented of methods and approaches that are in current use. **These are not an exhaustive description of all methods for addressing the checkerboard effect.** Practitioners are encouraged to develop additional solutions.

# CIM Journal Article

GEOLOGY 1

**The checkerboard effect and mineral resource reporting of underground mineral resources**

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**ABSTRACT** The goal of a Mineral Resource statement is to estimate the in-situ tonnage and grade that might reasonably be expected to be extracted using the contemplated mining methods. Despite the transition by the mining industry to the use of computer-aided methods for preparing Mineral Resource estimates, the fundamental realities of complying with the CIM Definition Standards requirement of "Reasonable Prospects for Eventual Economic Extraction" (RPEEE) have not changed. Computer-aided block modeling can result in an irregular, patchwork of blocks above and below cutoff grade, termed the checkerboard effect. In such cases, for underground mining methods, strict application of a block cutoff grade does not consider the impact of any internal dilution blocks that may be present, while also potentially including blocks above cutoff grade that may not have sufficient spatial continuity. Considering the block dimensions relative to the selectivity of the potential underground mining method, this can result in material errors in Mineral Resource statements. The impact of the checkerboard effect varies from deposit to deposit. While several techniques are currently employed by Mineral Resource practitioners to ensure compliance with the RPEEE requirement of a Mineral Resource, practitioners are encouraged to develop additional methods and techniques that provide reasonable results.

**KEYWORDS** Block model, Checkerboard effect, Constraining surfaces, Constraining volumes, Internal dilution, Mineral resources, Reasonable prospects, Underground mining method

RÉSUMÉ Le but d'un énoncé des ressources minérales consiste à estimer le tonnage et la teneur in situ qui pourraient raisonnablement être extraits à l'aide des méthodes d'extraction envisagées. Malgré la transition de l'industrie minière vers l'utilisation de méthodes assistées par ordinateur pour la préparation des estimations des ressources minérales, les réalités fondamentales du respect de l'exigence des normes de définition de l'ICM concernant les perspectives raisonnables d'extraction économique éventuelle (RPEEE, de l'anglais *Reasonable Prospects for Eventual Economic Extraction*) n'ont pas changé. La modélisation de blocs assistée par ordinateur peut donner lieu à un patchwork irrégulier de blocs au-dessus et en dessous du seuil de teneur limite appelé effet de damier. Dans de tels cas, pour les méthodes d'exploitation souterraine, l'application stricte d'une teneur limite de bloc ne tient pas compte de l'impact des blocs de dilution interne qui peuvent être présents, tout en incluant potentiellement des blocs au-dessus de la teneur limite qui peuvent ne pas avoir une continuité spatiale suffisante. Compte tenu des dimensions des blocs par rapport à la sélectivité de la méthode d'extraction souterraine potentielle, cela peut entraîner des erreurs importantes dans les énoncés des ressources minérales. L'impact de l'effet damier varie d'un dépôt à l'autre. Bien que plusieurs techniques soient actuellement utilisées par les praticiens des ressources minérales pour assurer la conformité à l'exigence de la RPEEE d'une ressource minérale, les praticiens sont encouragés à élaborer d'autres méthodes et techniques qui fournissent des résultats raisonnables.

**MOTS-CLÉS** dilution interne, effet de damier, méthode d'extraction souterraine, modèle de bloc, perspectives raisonnables, ressources minérales, surfaces de contrainte, volumes de contrainte

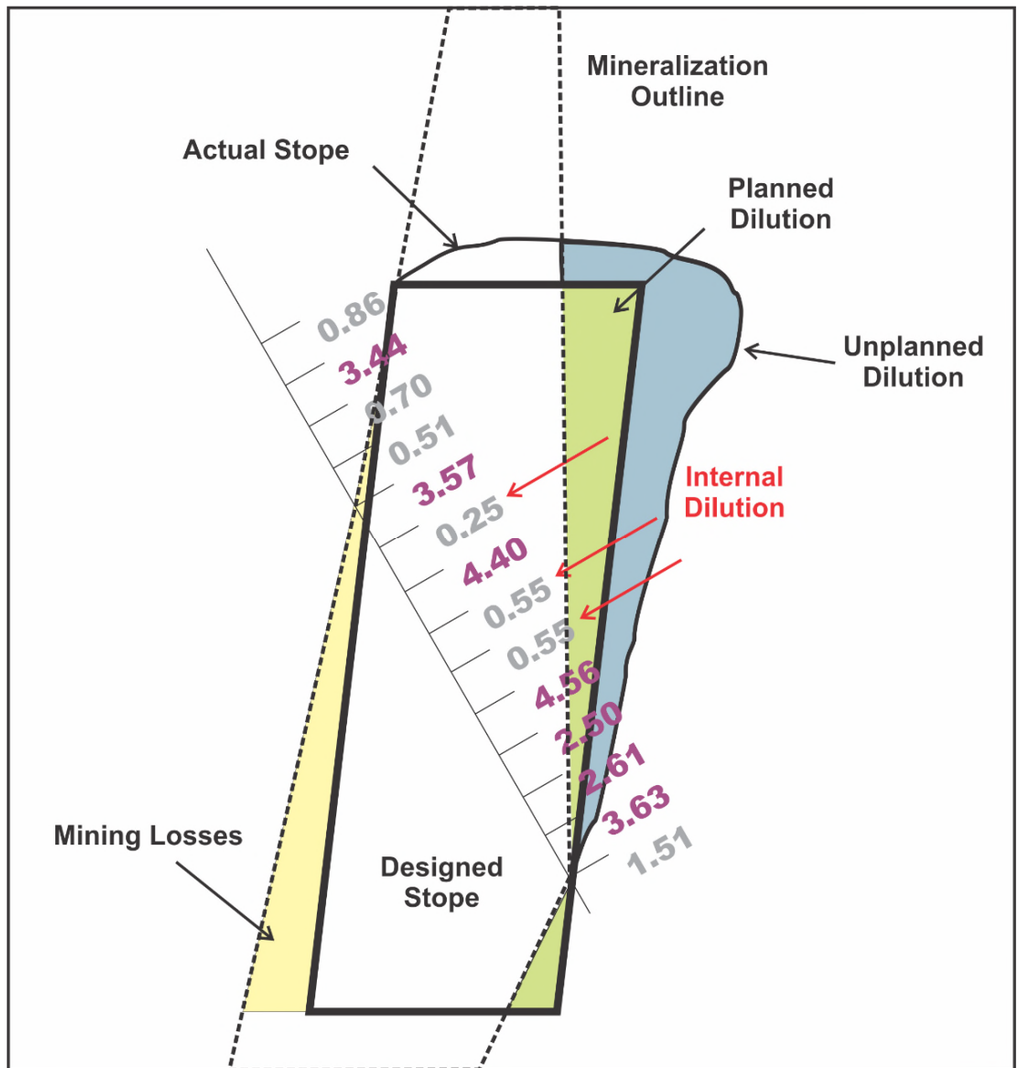
- Additional discussion on The Checkerboard Effect can be found in an article published in the CIM Journal, Volume 12, Issue 1 (April, 2021).
- Copies of the article are available to CIM members at:

  www.cim.org/library/cim-journal/

- Additional discussion on the RPEEE requirement for Mineral Resource statements is available in **Chapter 6** of the CIM Mineral Resources and Mineral Reserves Best Practices Guidelines.

# CONCEPTS

# Dilution Terminology - Underground




Several types of dilution are often encountered in underground mining situations. While they can be referred to by various means, they fall into three main types:

**Internal dilution:** material below the cut-off grade that cannot be selectively excluded by the mining method

**Planned dilution:** material below the cut-off grade that must be excavated due to the requirement of the mining method, and

**Un-planned dilution:** also referred to as "over-break". Material below the cut-off grade that is unintentionally excavated.

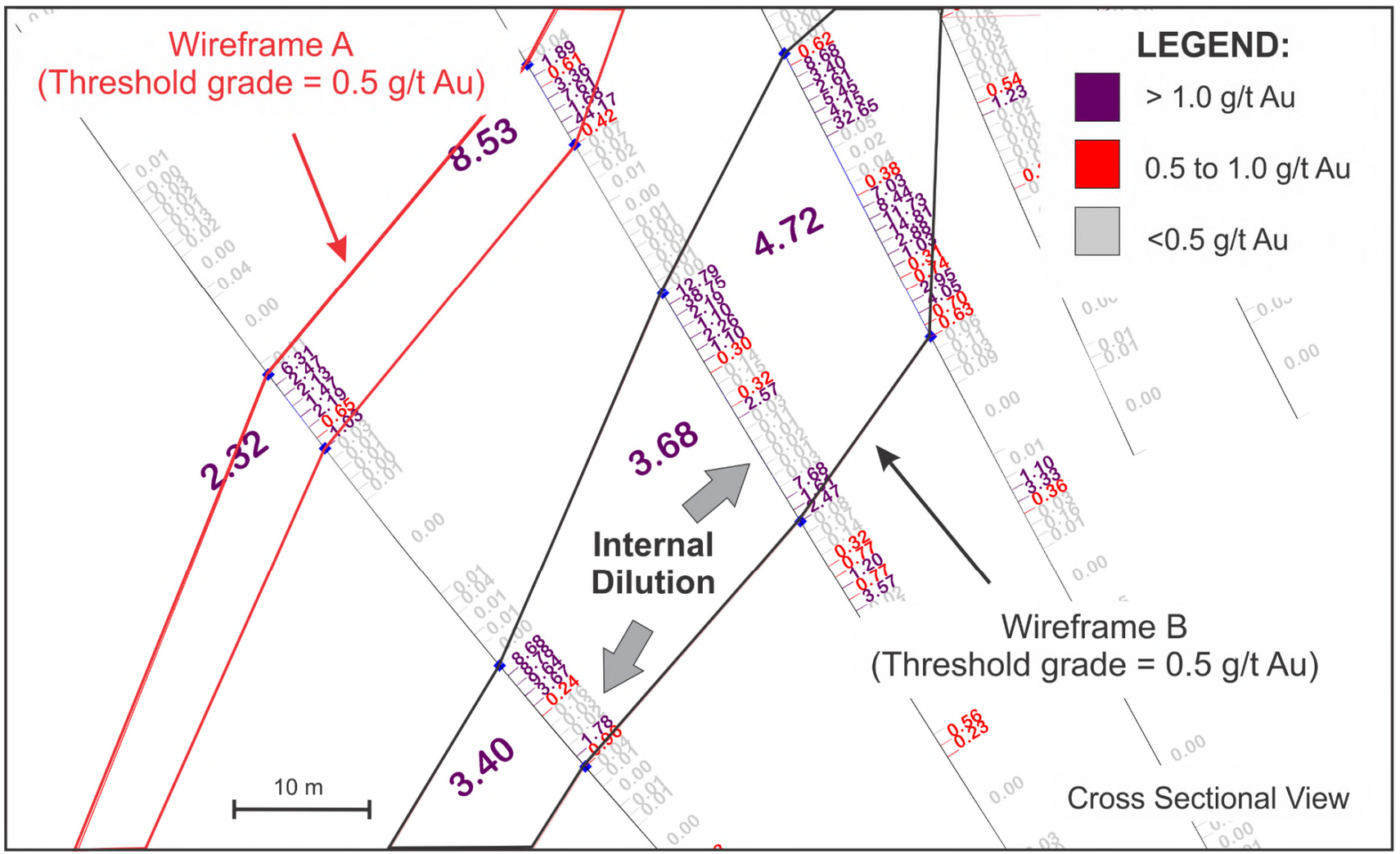
Mineral Resources have historically included internal dilution. Planned and unplanned dilution were considered as part of the Mineral Reserve estimate.

# Mineralization and Internal Dilution – UG setting


In many cases mineralization can occur in such a manner such that some of the non-mineralized material (internal dilution) must be excavated along with the mineralization.

Despite the transition to the use of computer software as aids in the preparation of Mineral Resource estimates in the past few decades, this characteristic has remained a constant in the mining industry.

# Internal Dilution – UG setting

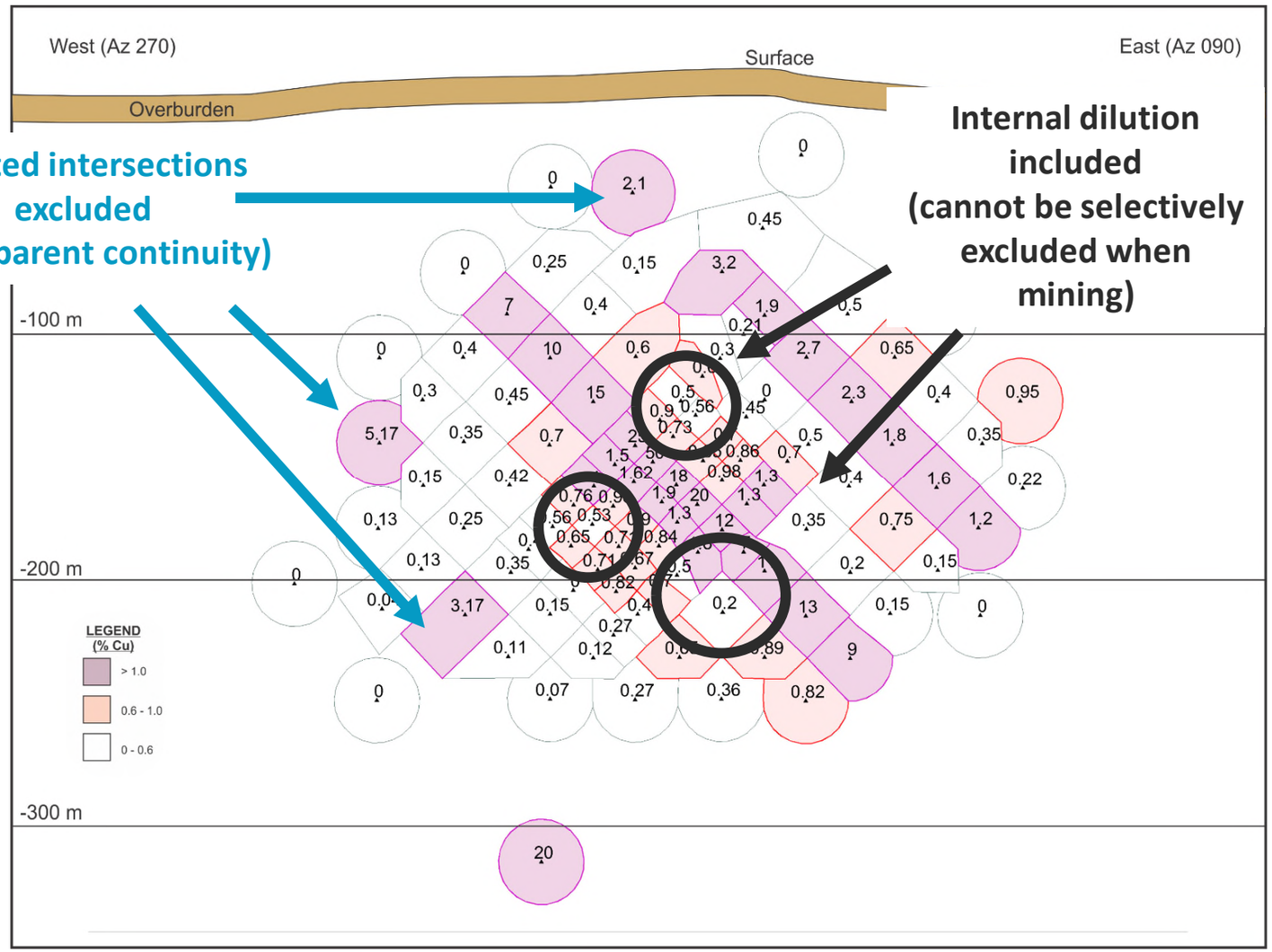



The process of preparing interpretations of the mineralization continues to be a key step in Mineral Resource estimation.

Rather than being done by hand on paper, this is now most commonly done by digital means.

However, the underlying fundamental considerations remain unchanged (cut-off grade, minimum width considerations, spatial continuity, and internal dilution).

# Polygonal Estimate Example – Manual Tabulation

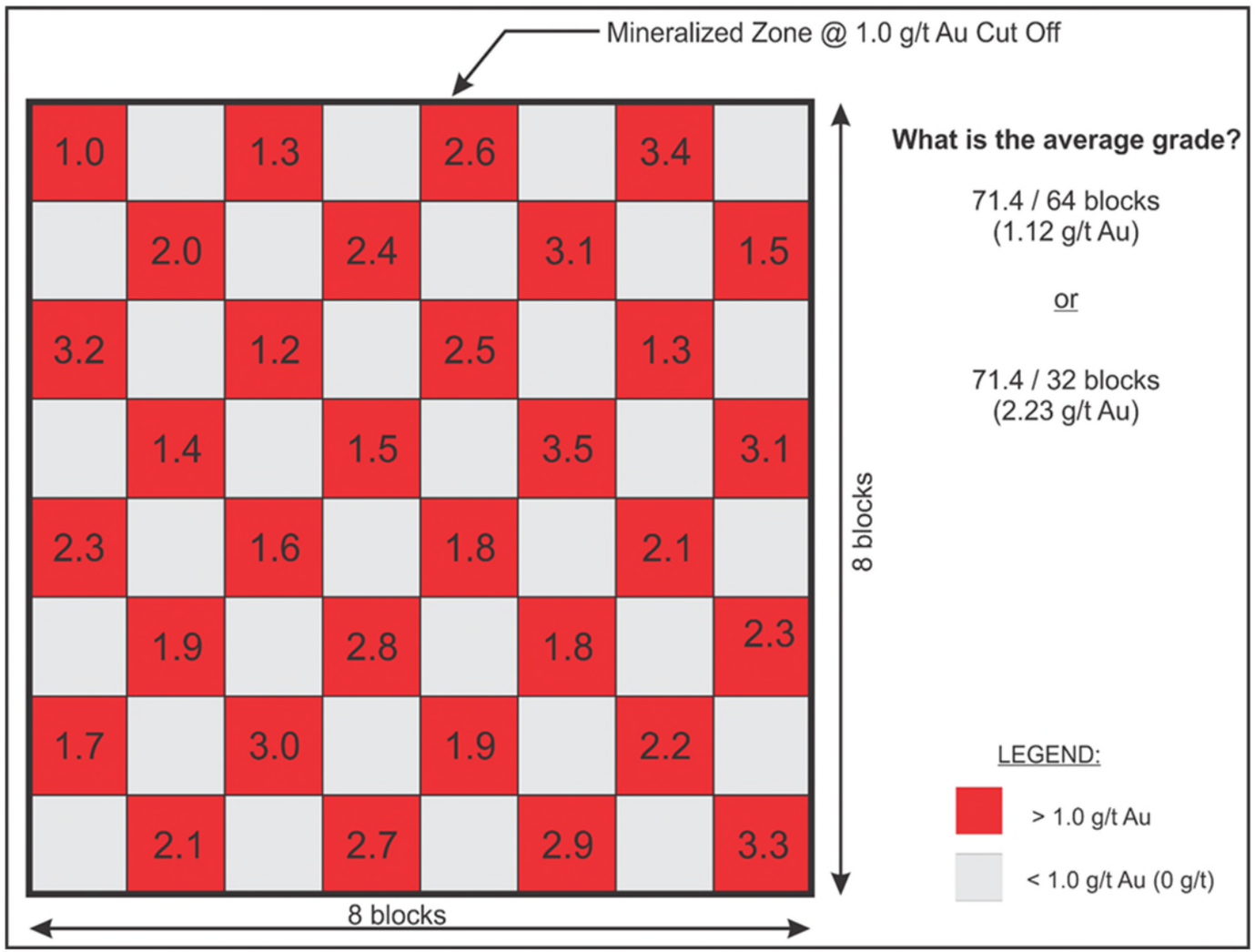



Because the tabulation of the Mineral Resources were historically done by hand, the inclusion or exclusion of desired or undesired blocks was easily achieved.

This process is more difficult to achieve using computer software. A common approach in the digital age is to report all blocks above a cut-off grade (i.e. using a “block cut-off”).

This approach can have unintended results.

# Impact of Block Cut-off Grades




To understand the concept, it is useful to think of a checkerboard where the red blocks have grades above the cut-off grade and the grey blocks have a grade of zero.

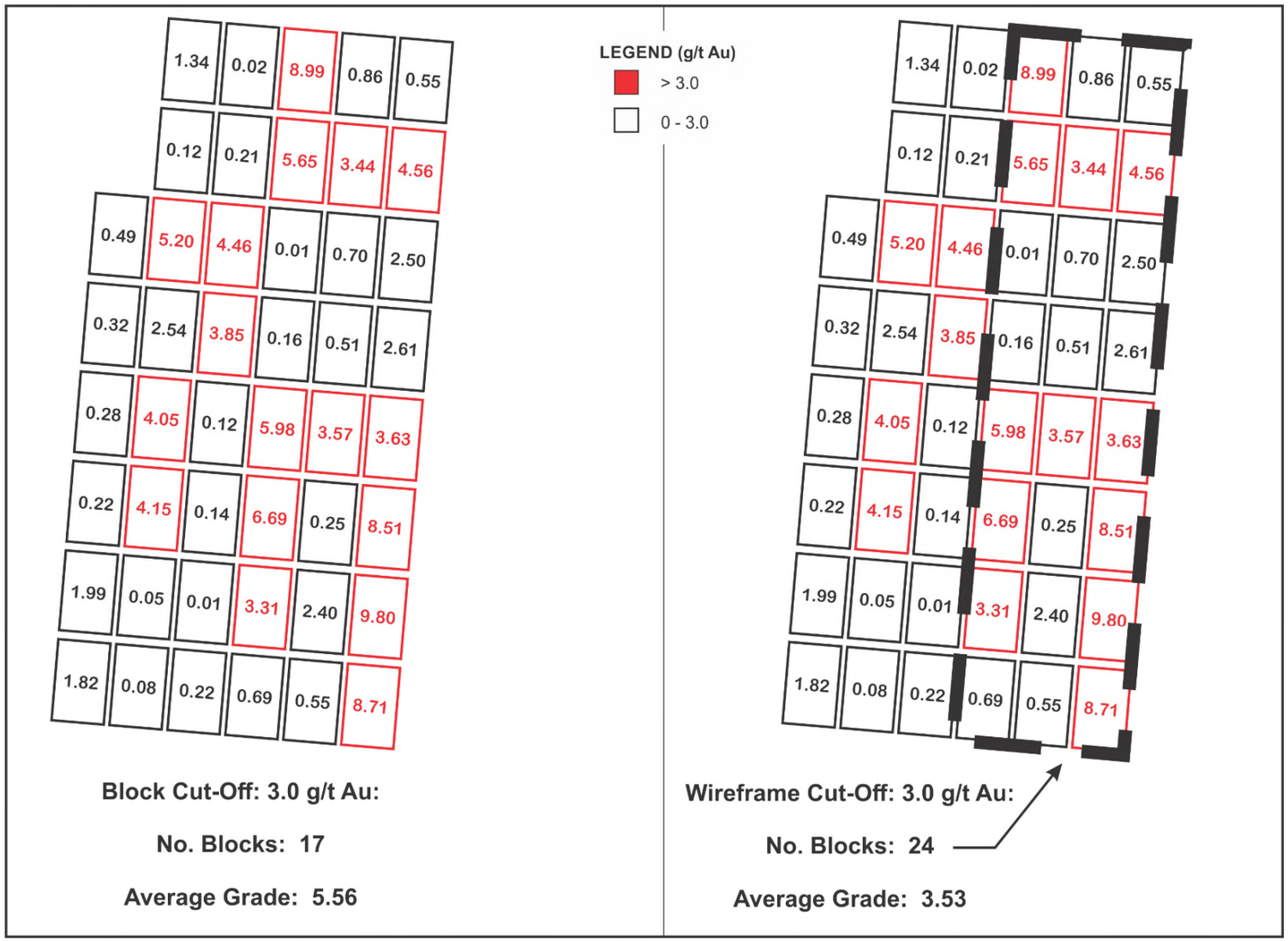
Assume that the minimum potential underground mining unit is much larger than the blocks.

The correct answer in this case is 1.12 g/t Au (71.4 divided by 64 blocks).

Reporting of only the blocks above the cut-off grade (the red blocks), we have an answer of 2.23 g/t Au (71.4 divided by 32 blocks).

This is a result of reporting bias that does not consider spatial continuity.

# Consideration of Spatial Continuity



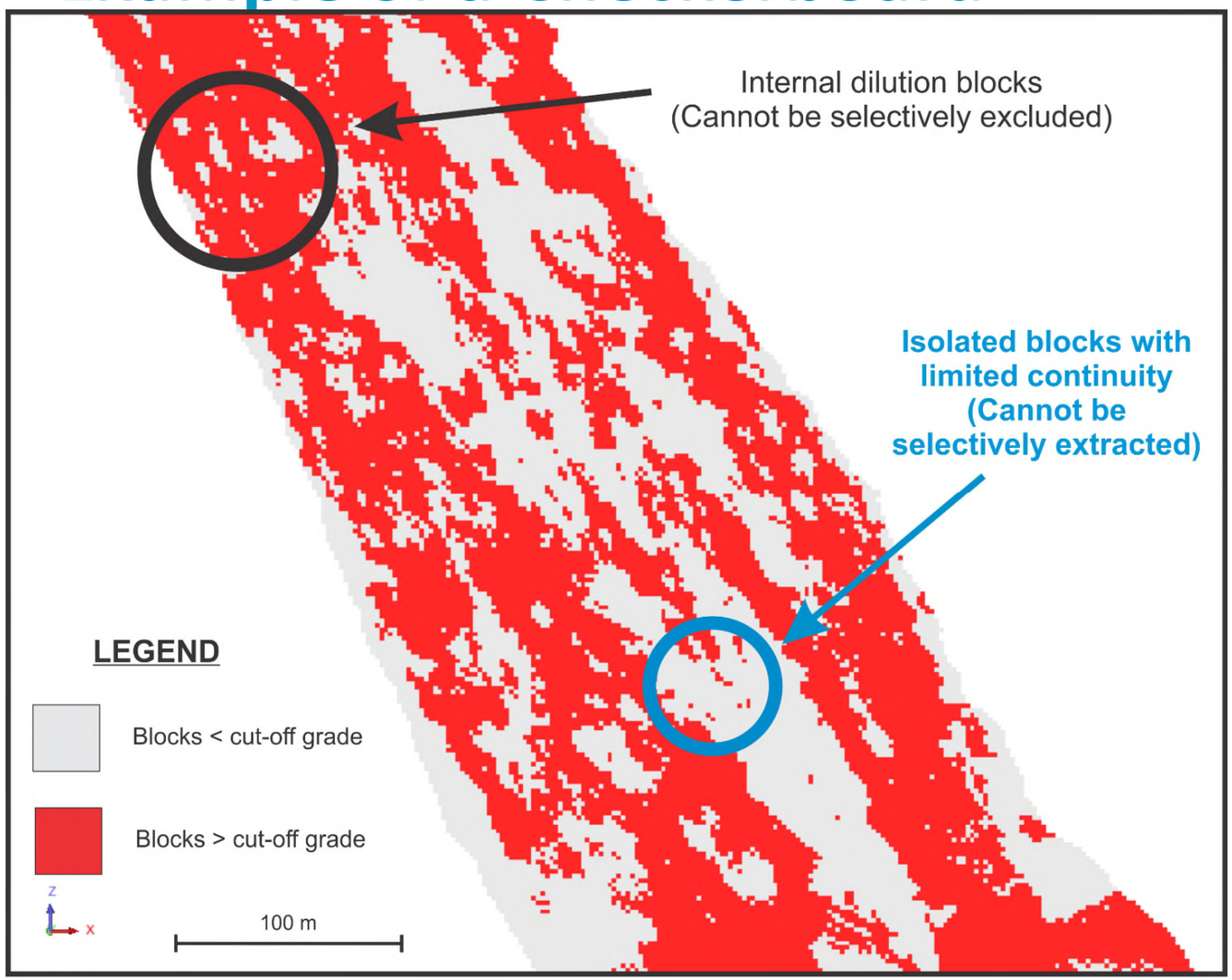

The same effect occurs when applying a block cut-off grade when reporting from a block model.

The left-hand pane applies a block cut-off grade that results in a report of 17 blocks at an average grade of 5.56 g/t Au.

The right-hand pane applies a spatial constraint reflecting conceptual mining constraints.

This results in a report of 24 blocks at an average grade of 3.53 g/t Au.

# Example of a Checkerboard

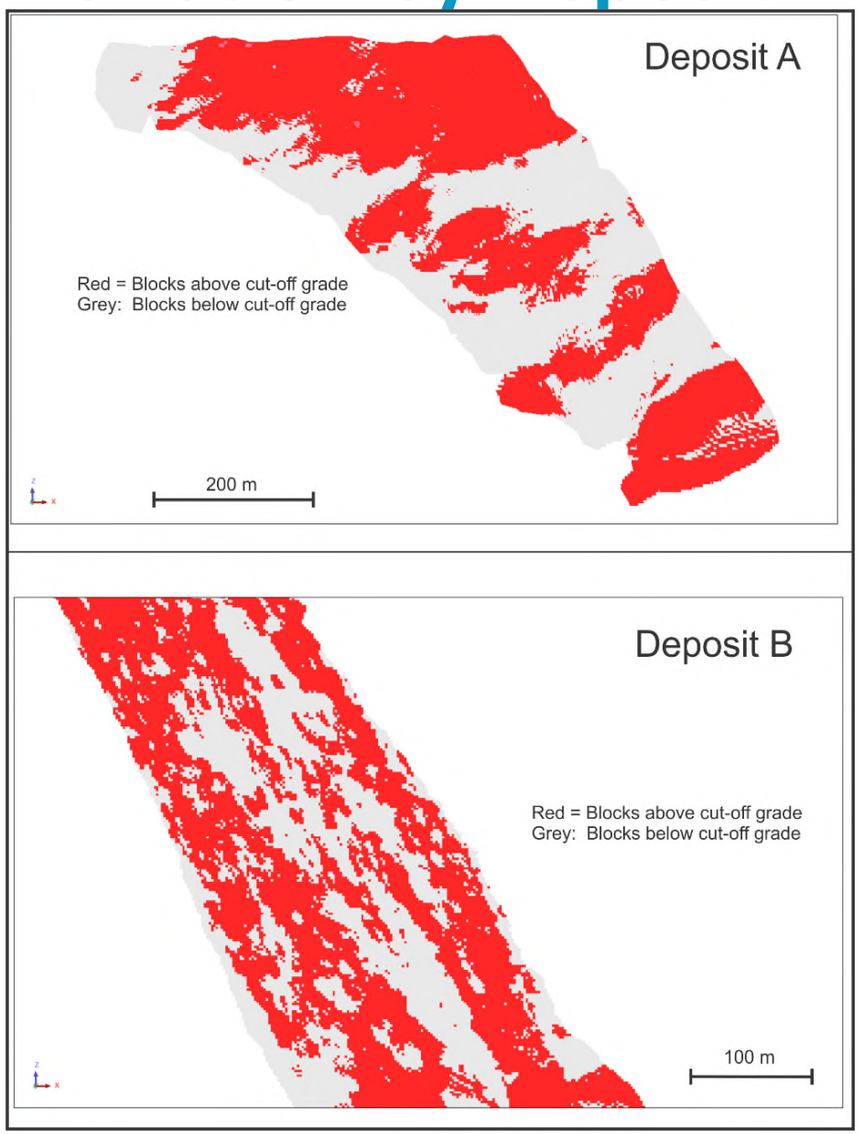



The problem with using solely block cut-off grades lies with the implied mining selectivity of the block size in the model. In many cases, the block sizes for modelling underground mineralized zones is significantly smaller than what can be achieved during normal-course operations.

Selectivity includes the ability to exclude internal dilution from mineralized areas and the ability to extract small areas of mineralization without associated diluting materials.

The degree of “checkerboarding” varies from deposit to deposit. The severity of the checkerboard also depends on the cut-off grade used to prepare the Mineral Resource statement.

# Variation by Deposit




The impact of the checkerboard effect will vary with each deposit.

In fact, the impact of the checkerboard effect can vary with different mineralized zones within a single deposit.

# Variation by Cut-off Grade

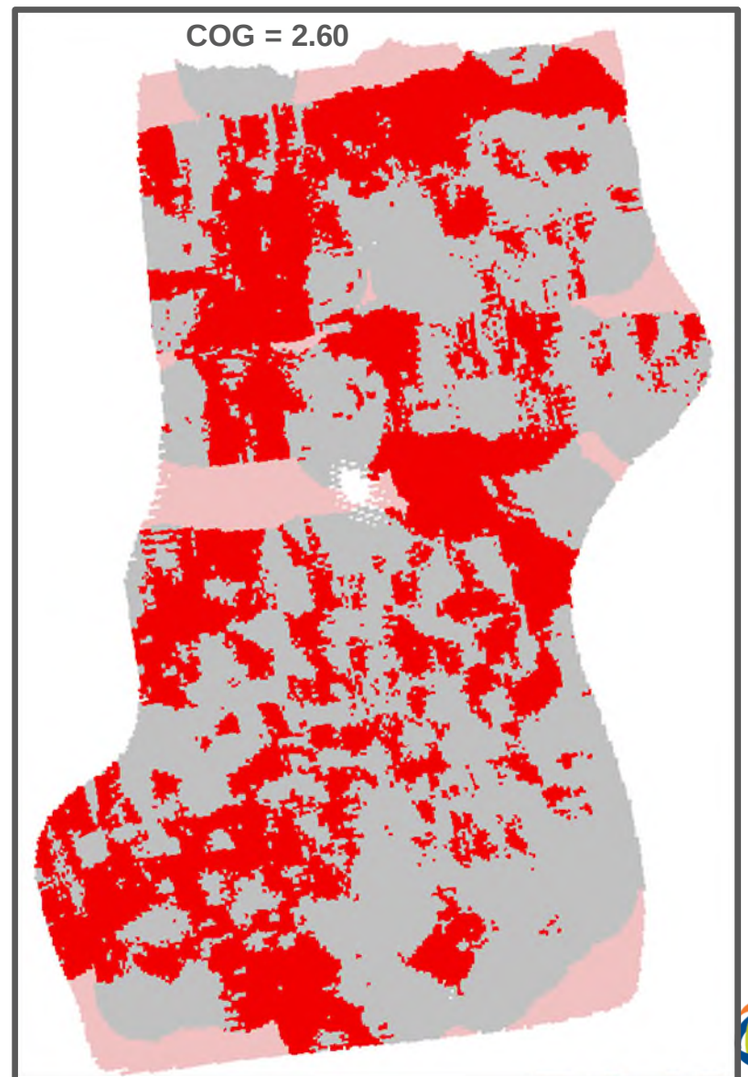

**LEGEND:**
Pink = Un-estimated Blocks
Grey = Blocks Below Cut-Off
Red = Blocks Above Cut-Off

200 m

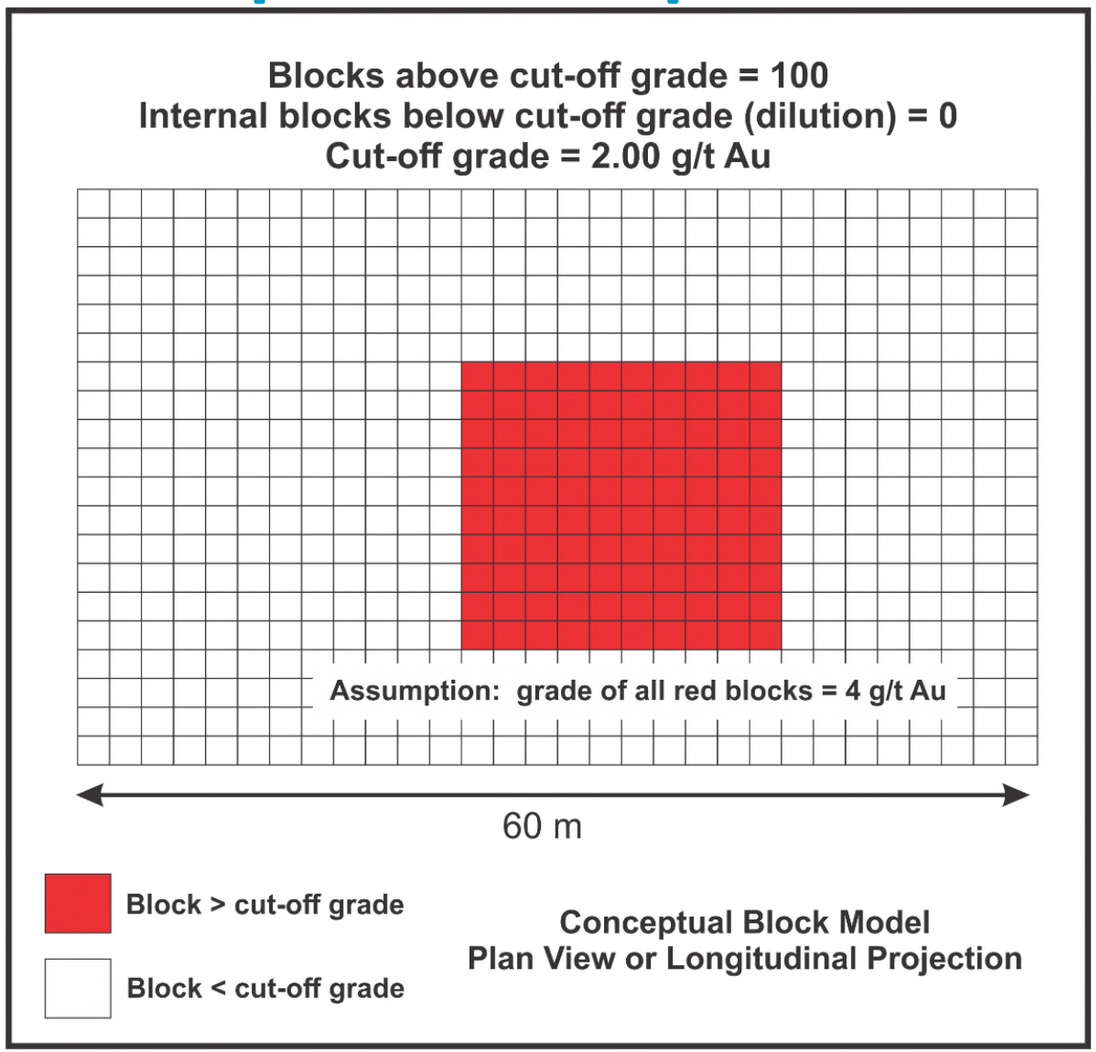
The impact of the checkerboard effect will vary as the cut-off grade changes.

In general, higher cut-off grades will result in reduced spatial continuities.

This will result in a greater impact when using simple block cut-off grades for preparing Mineral Resource statements.



# Conceptual Examples of the Checkerboard Effect




The checkerboard effect can be manifested in different ways depending on the nature of the grade distribution in a given deposit.

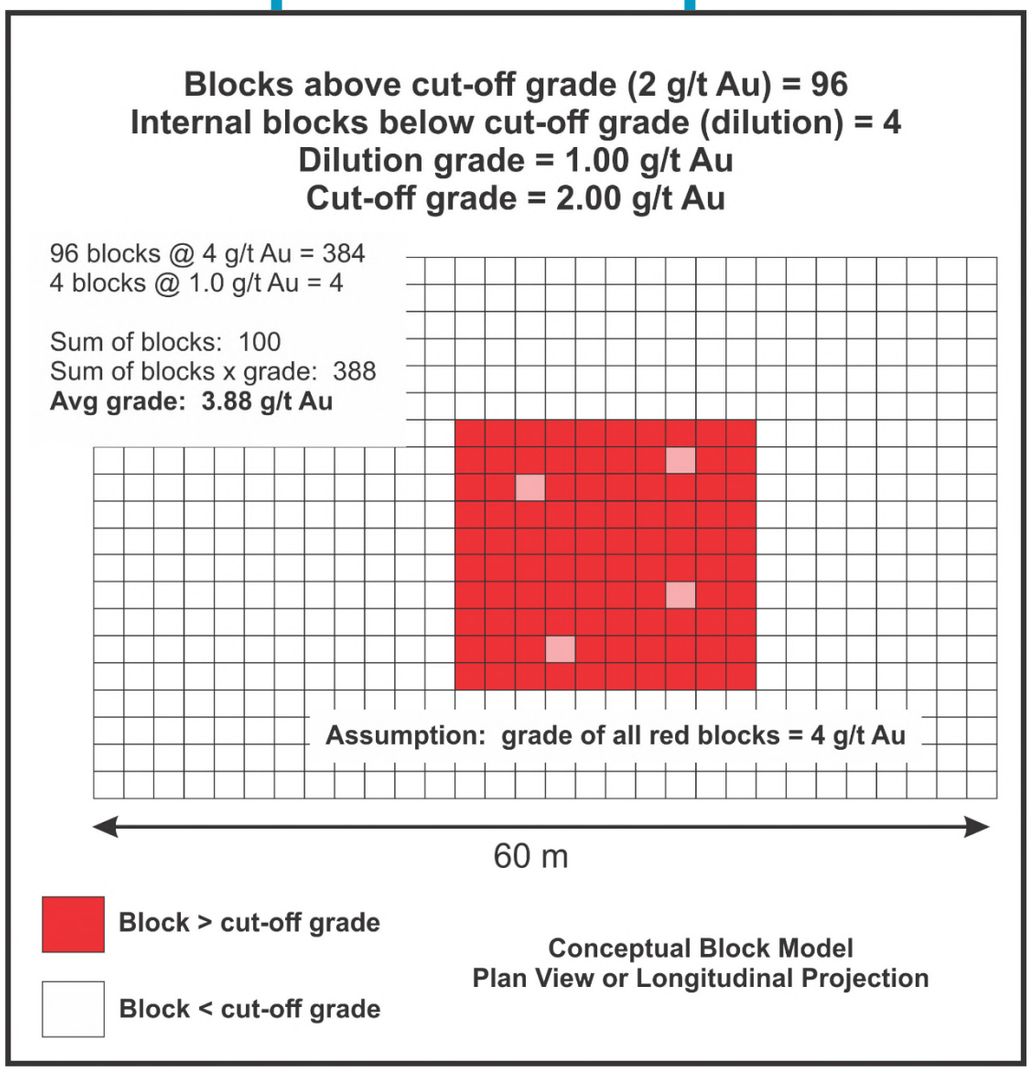
The following are selected conceptual examples to examine the underlying concepts affecting the results. Specific results in real-world settings will vary on a case-by-case basis.

In this example we have 100 blocks each with a grade of 4.00 g/t Au.

Application of a block cut-off grade alone (COG = 2.00 g/t Au) yields a report of 100 blocks at an average grade of 4.00 g/t Au.

An acceptable result for this situation where there are no internal dilution blocks within the red area.

# Conceptual Examples of the Checkerboard Effect



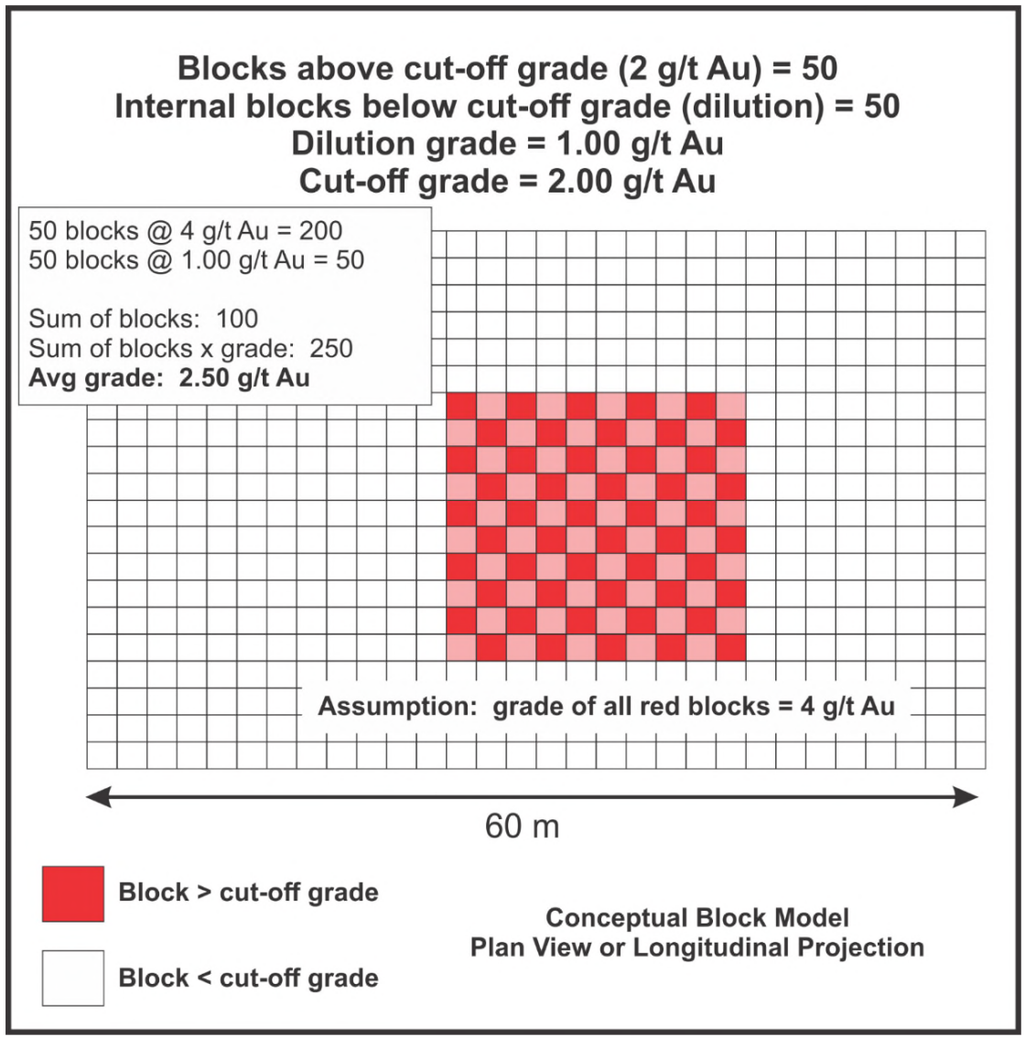

For this example, we consider the presence of a minor amount of internal dilution where the grade of each diluting block is assumed to be 1.00 g/t Au.

The correct result in this case is 100 blocks at an average grade of 3.88 g/t Au.

Application of a block cut-off grade alone (COG = 2.00 g/t Au) yields a report of 96 blocks at an average grade of 4.00 g/t Au.

Although not strictly correct, some Mineral Resource practitioners may consider this result to be acceptable in these types of situations with minimal internal dilution blocks.

# Conceptual Examples of the Checkerboard Effect




For this example, we consider the presence of a large amount of internal dilution where the grade of each diluting block is assumed to be 1.00 g/t Au.

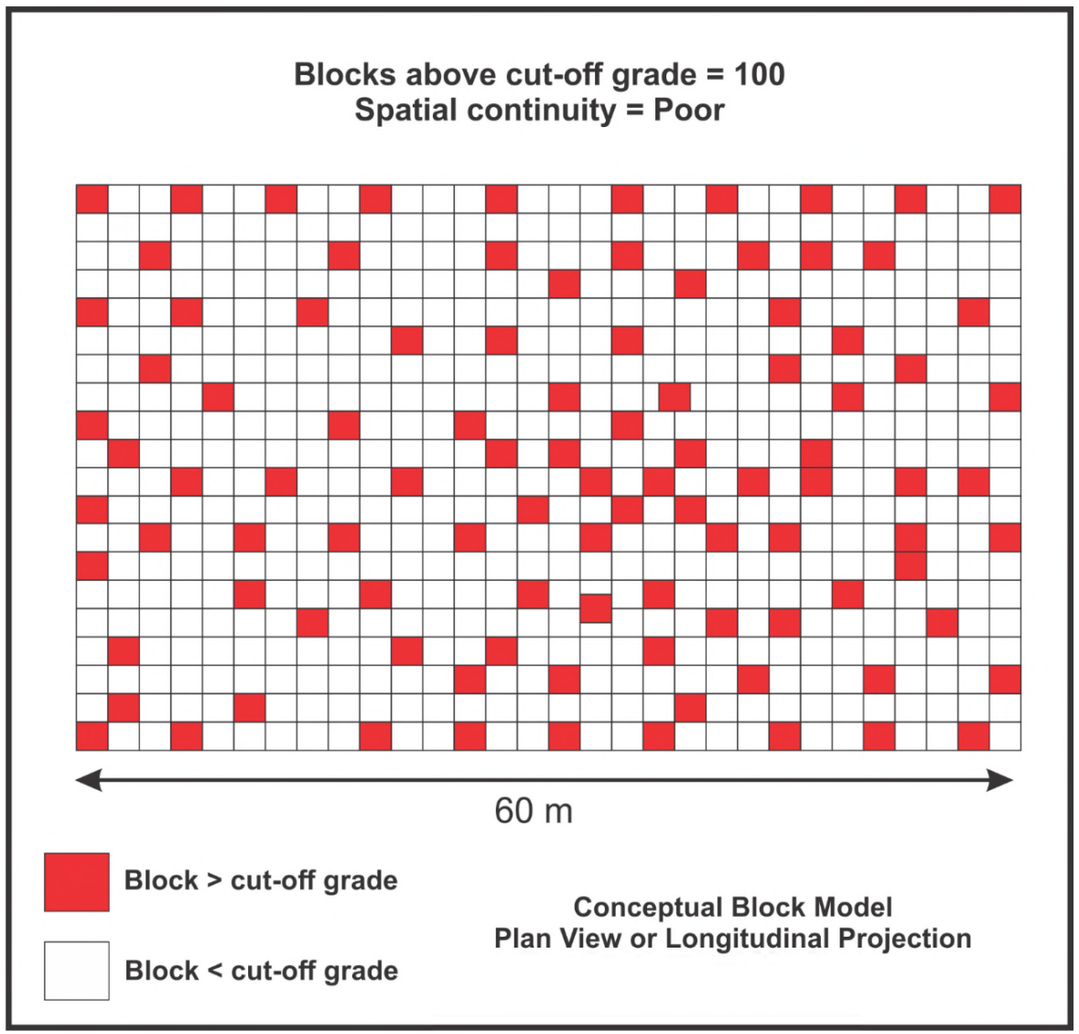
The correct result in this case is 100 blocks at an average grade of 2.50 g/t Au.

Application of a block cut-off grade alone (COG = 2.00 g/t Au) yields a report of 50 blocks at an average grade of 4.00 g/t Au.

This is a significantly higher grade represented by only half the number of blocks (tonnes).

Assuming that the block size is much smaller than can be achieved by the contemplated underground mining method, strict application of a block cut-off grade will likely be considered as unacceptable by the Mineral Resource practitioner.

# Conceptual Examples of the Checkerboard Effect




For this example, we consider the case where the spatial continuity of the blocks above the cut-off grade is extremely poor.

The correct result in this case is uncertain at best.

Application of a block cut-off grade alone (COG = 2.00 g/t Au) yields a report of 100 blocks at an average grade of 4.00 g/t Au.

This is an unrealistic outcome in this example due to the lack of spatial continuity of the blocks above cut-off grade.

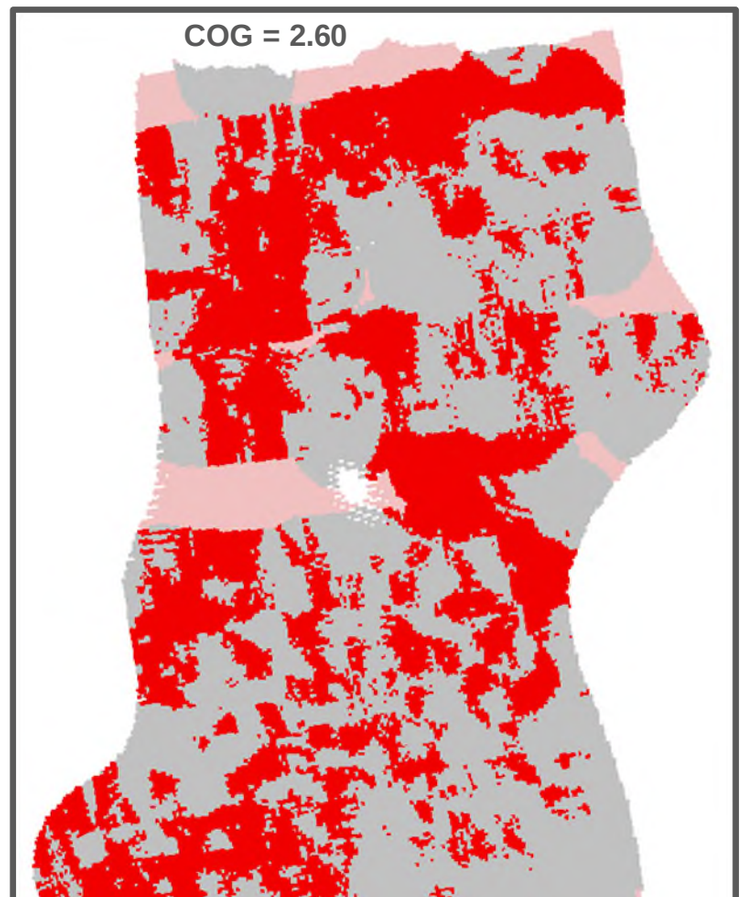
Thought Example:  A block cave situation.

# Checkerboard Effect – Case History


**LEGEND:**
Pink = Un-estimated Blocks
Grey = Blocks Below Cut-Off
Red = Blocks Above Cut-Off

200 m

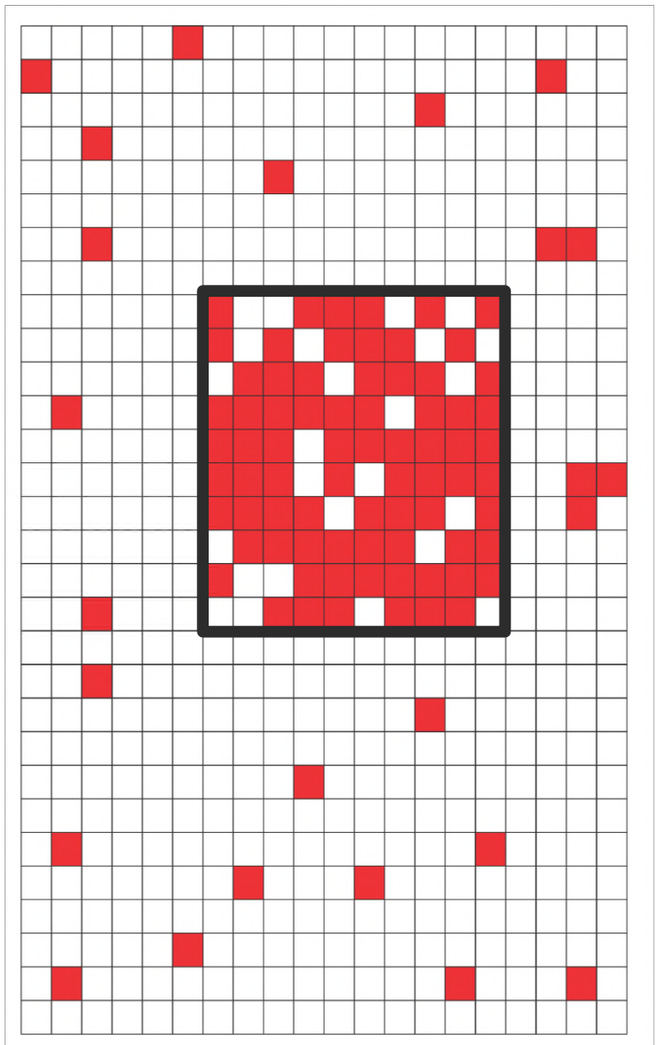
Reporting using block cut-off grades along can result in undesired outcomes!




| Internal Dilution | Tonnes | Grade (g/t) | Oz Au |
|---|---|---|---|
| Included | 1,160,000 | 2.65 | 98,600 |
| Excluded | 1,130,000 | 2.71 | 98,300 |
| % Difference | + 3% | - 2 % | 0 % |

| Internal Dilution | Tonnes | Grade (g/t) | Oz Au |
|---|---|---|---|
| Included | 1,160,000 | 2.65 | 98,600 |
| Excluded | 481,000 | 4.03 | 62,400 |
| % Difference | + 140 % | - 35 % | + 58 % |

# Section 6.12.2 Constraining Surfaces & Volumes



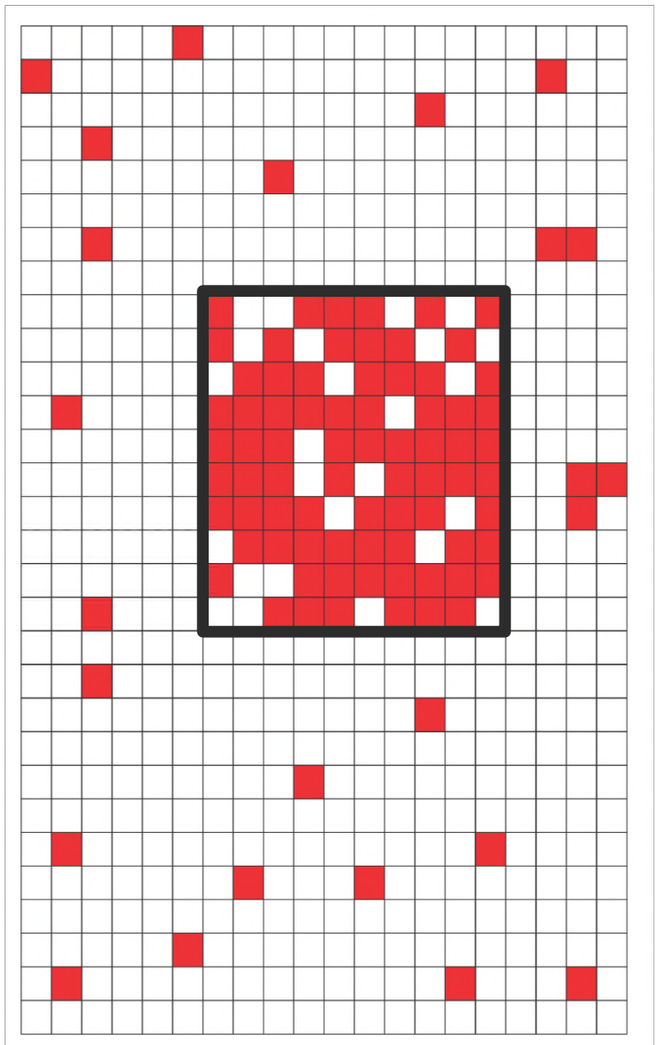
Mineral Resource statements for underground mining scenarios must satisfy the “reasonable prospects for eventual economic extraction” by demonstration of the spatial continuity of the mineralization within a potentially mineable shape.

In cases where this potentially mineable volume contains smaller zones of mineralization with grades or values below the stated cut-off (sometimes referred to as “must take” material), this material must be included in the Mineral Resource estimate.

At a minimum, these constraints can be addressed by creation of constraining volumes.

Constraining volumes should be used in conjunction with other criteria for the preparation of Mineral Resource estimates.

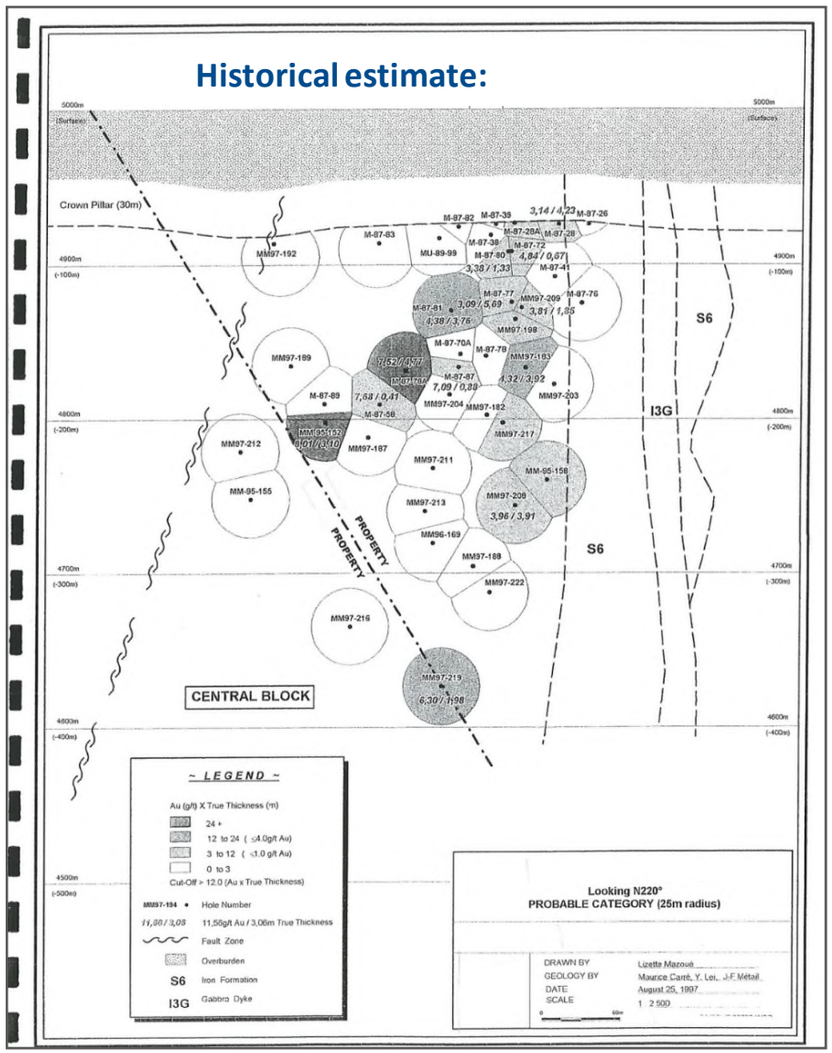
# Section 6.12.2 Constraining Surfaces & Volumes



In many cases where the Mineral Resource estimate is prepared by digital methods, isolated and discontinuous blocks may be present that have grades or values above the stated cut-off grade or value.

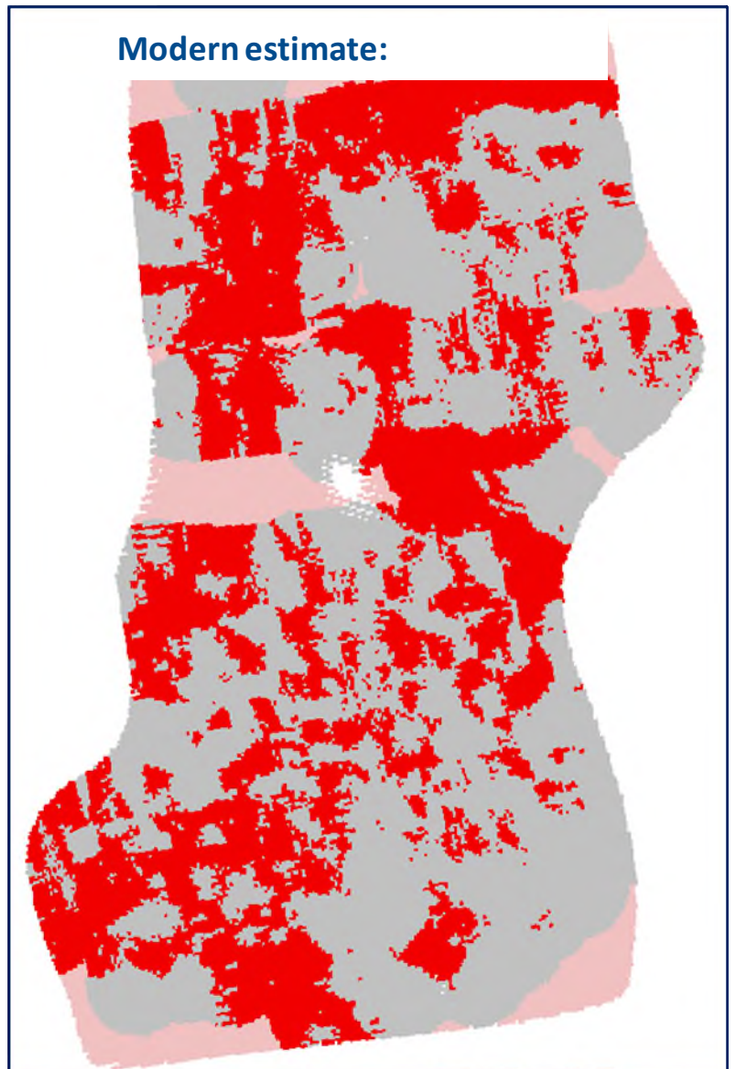
For underground mining methods, these blocks should be excluded from the Mineral Resource statement if their spatial continuity or their size is insufficient to achieve a potentially mineable shape above the nominated cut-off grade or value.

# A Very Old Conversation



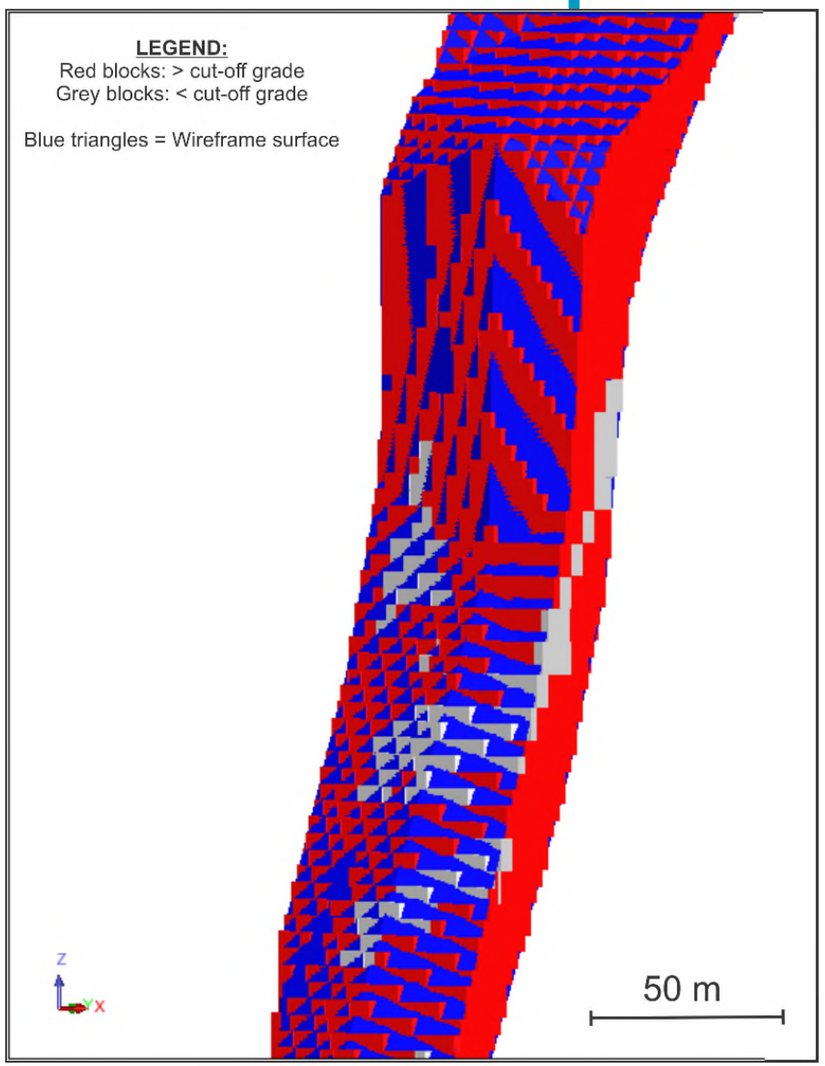

Historical methods or modern methods - **it's the same old discussion!**

**The only new item is the use of computers in preparing Mineral Resource statements.**



# SOLUTIONS

# Solutions – Report all blocks inside a wireframe

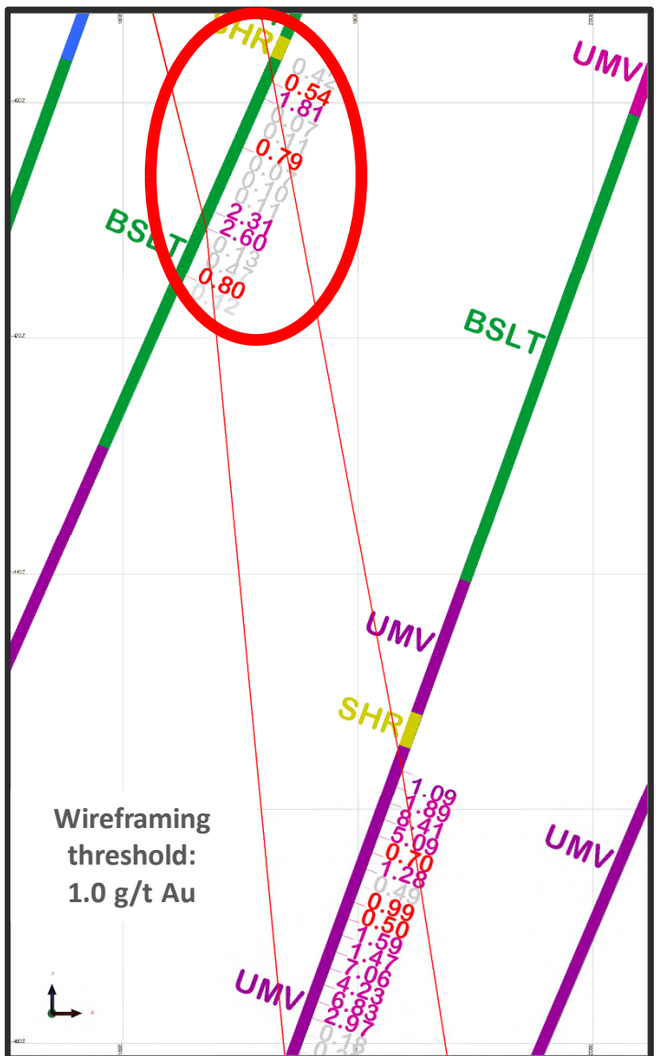



In some situations, the Mineral Resource practitioner is able to create a wireframe volume which describes only the mineralized volume at the stated cut-off grade - a traditional approach.

In these cases, the Mineral Resource statements can be created by reporting all blocks contained within the mineralized wireframe volume, inclusive of internal dilution blocks.

This approach can be challenging to achieve functional wireframes.

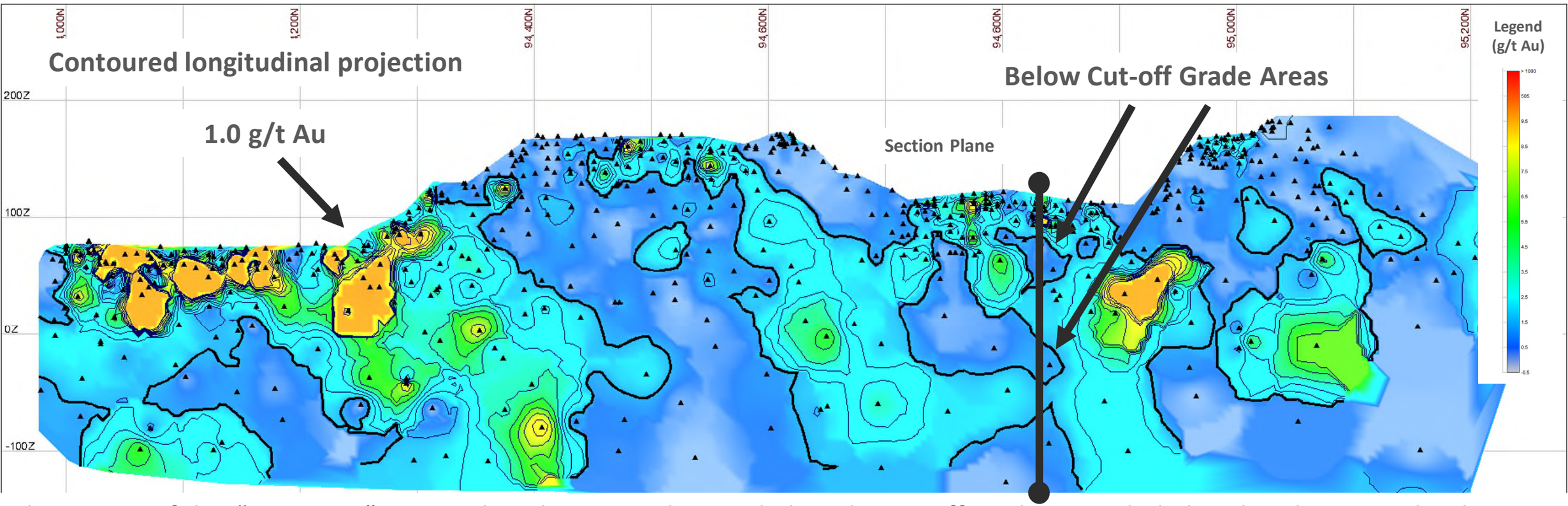
# Wireframe Interpretation Strategies




In some situations, the Mineral Resource practitioner may create a mineralized wireframe interpretation that includes some informing samples that are below the wireframe cut-off grade.

This approach is often warranted, as the controlling feature of the mineralization may still be present, but the metal grades in that specific location in space are below the cut-off grade at that point in time.

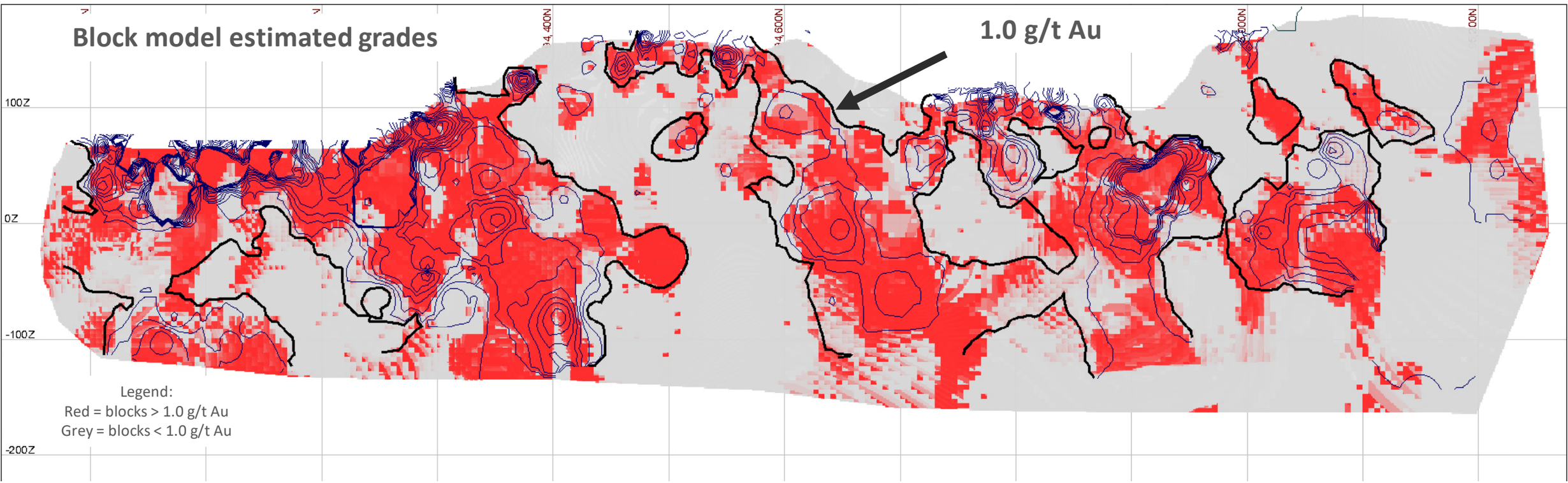
# Wireframe Interpretation Strategies




The impact of this "continuity" approach is that areas that are below the cut-off grade are included within the mineralized wireframe outline.

This is often highly beneficial for understanding the grade distributions for use in drill hole planning and for understanding results from variography studies.

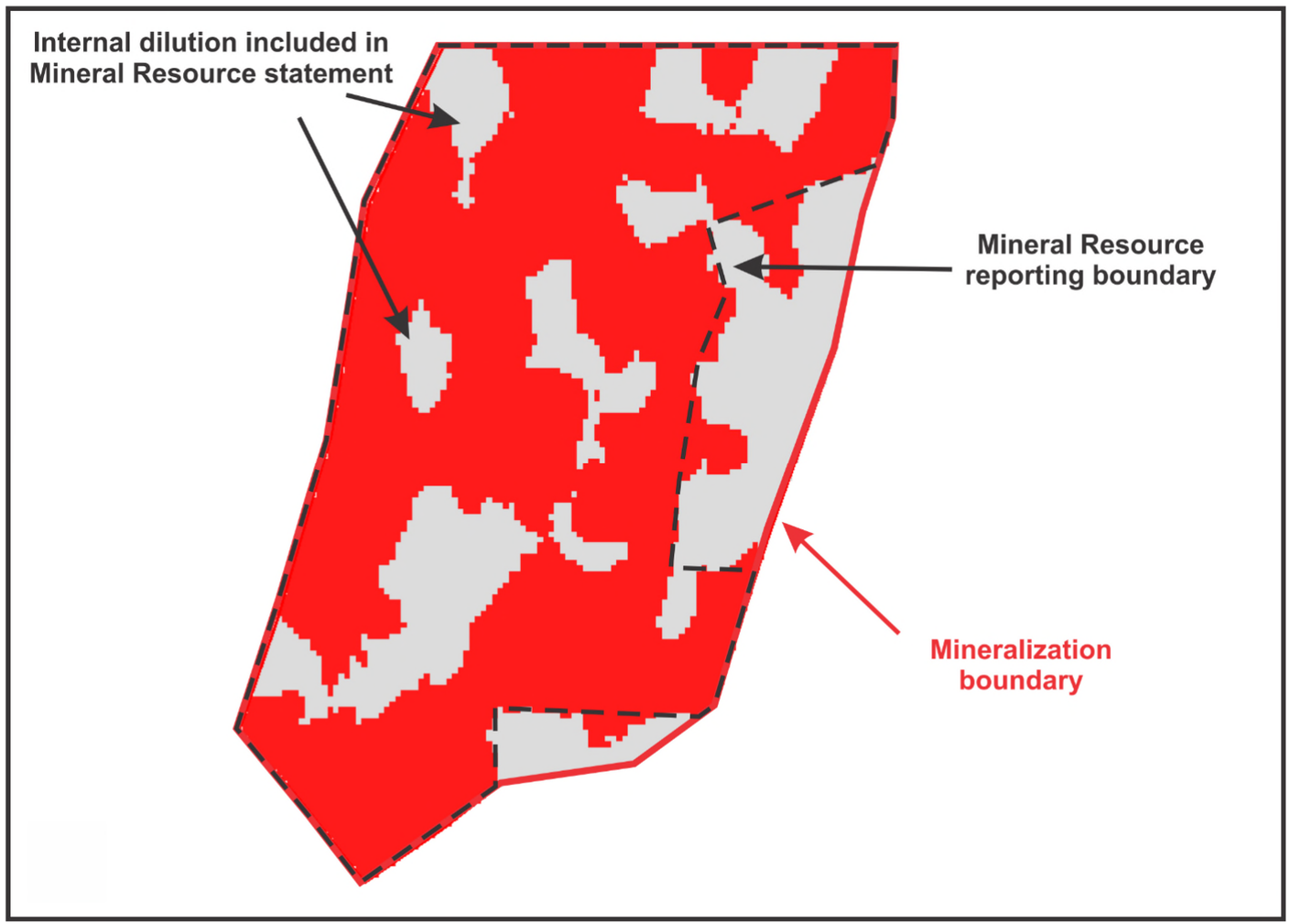
# Wireframe Interpretation Strategies




The drawback of the “continuity” approach is that the inclusion of below cut-off grade areas within the mineralized wireframe volume leads to blocks whose estimated grades are also below the cut-off grade.

This then creates the challenge of addressing the checkerboard effect in addition to the internal dilution that can be present within a given drill hole intercept (discussed previously).

# Solutions – Report blocks using a reporting boundary

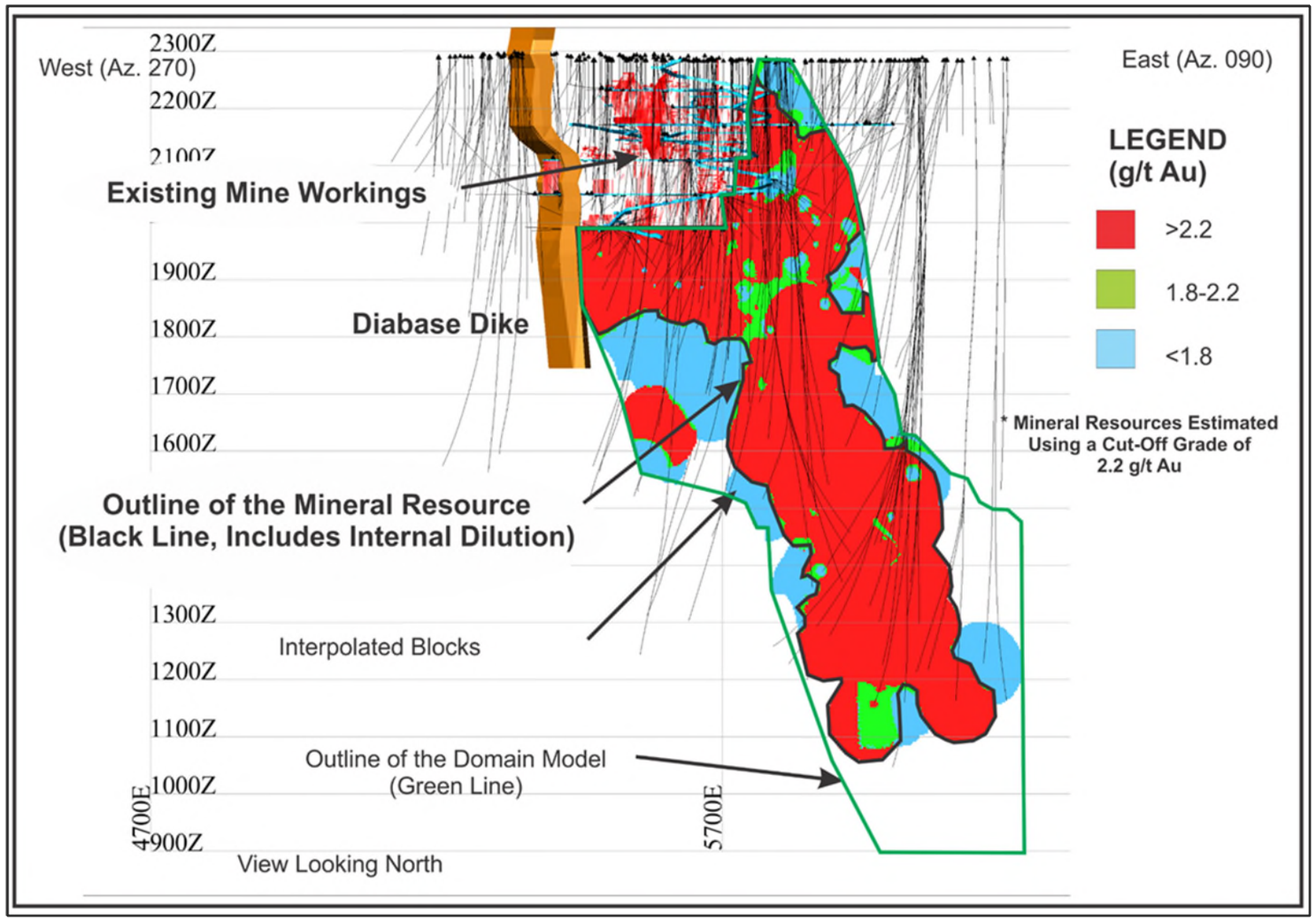



Additional reporting criteria are required in these cases.

One solution is to prepare constraining volumes through the use of clipping polygons to reflect the appropriate volumes for preparing Mineral Resource statements.

The Mineral Resource statement would then be a summation of all of the block tonnes and grade contained within the trimmed mineralization wireframes.

# Solutions – Manual Clipping Polygons

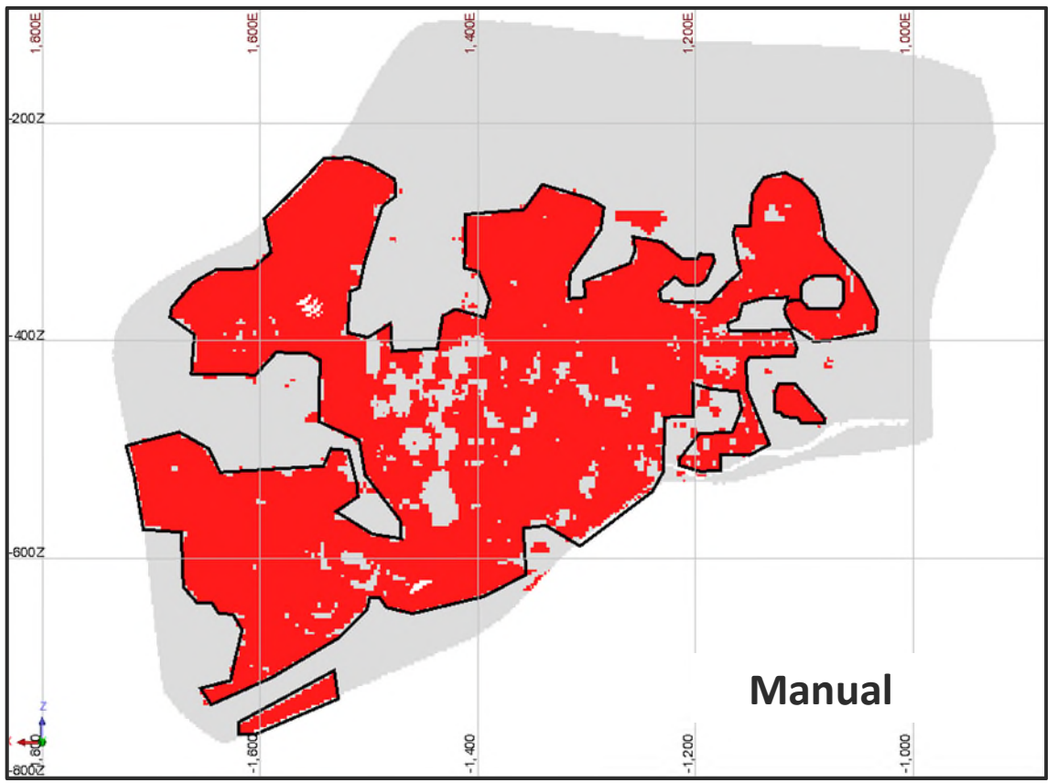


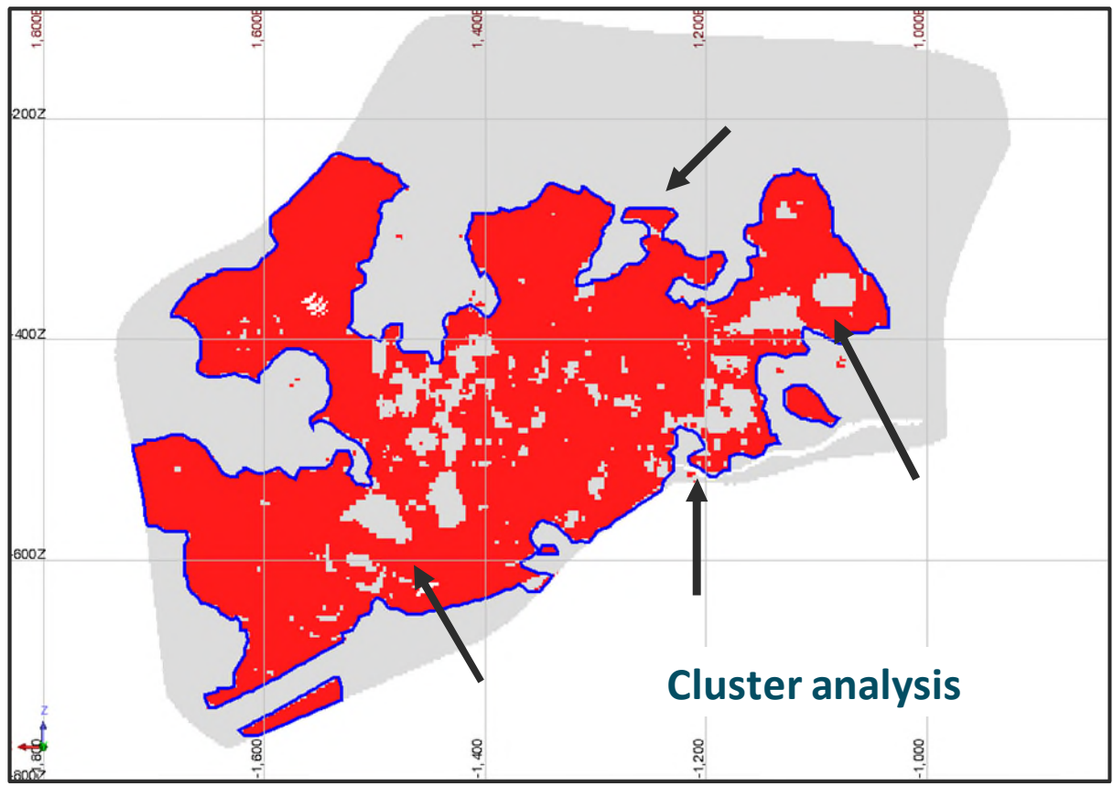

Constraining shapes can be drawn manually and then used to clip/trim the mineralized wireframe solid to include only those blocks to be included in the Mineral Resource statement.

Alternatively, some software packages will allow the clipping polygons to be used as an explicit constraint without the need to clip the source wireframe.

These manual methods allow the Practitioner to exercise their judgement and experience for preparing Mineral Resource statements.

# Solutions – Machine Learning

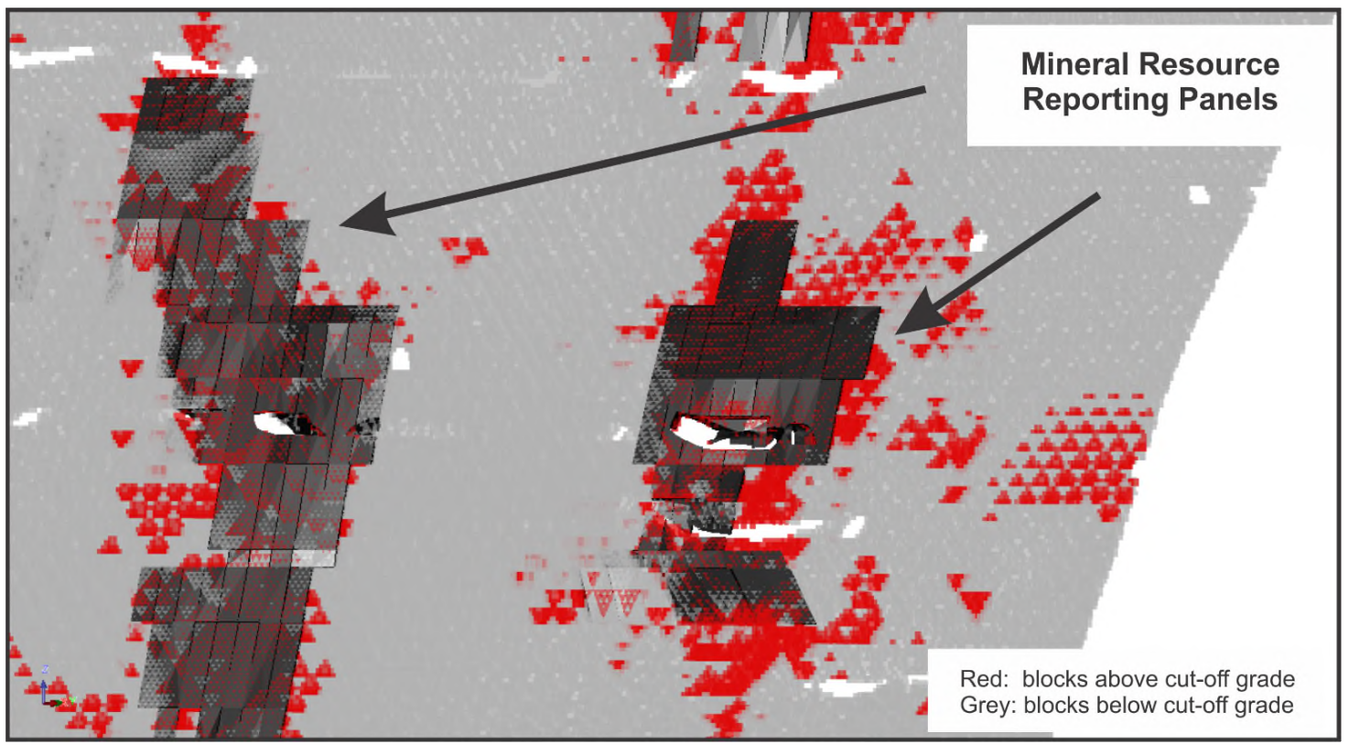



Manual methods clipping polygons are effective for dealing with a small number of cases, say less than 20.

Alternative methods are required to deal with larger number of cases. Machine learning can be used to automate the process.

# Solutions – Report blocks inside reporting panels




A common solution in use is the creation of reporting volumes generated by computer software programs.

The parameters selected as inputs for creation of these panels can be chosen to comply with the RPEEE requirement of the CIM Definition Standards for Mineral Resources.

The Mineral Resource statement would then be a summation of all of the block tonnes and grade contained within the reporting panels.

# WRAPPING UP

# Conclusions

- Computer-aided block modelling can result in an irregular, patchy mixture of blocks above and below the cut-off grade, termed the checkerboard effect.
- Block size relative to the minimum excavation size of the potential underground mining method must be considered to comply with the RPEEE requirement for Mineral Resources.
- The use of a simple block-above cut-off grade reporting criteria can yield undesired results when preparing Mineral Resource statements.
- While the severity of the checkerboard effect varies on a case-by-case basis, in some cases additional reporting criteria are required so that the RPEEE requirement of the CIM Definition Standards for Mineral Resources is satisfied.
- The use of constraining volumes are useful criteria for meeting this requirement.

# Acknowledgements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- We also wish to thank both the internal and external reviewers who graciously provided their time to review this paper and offer their thoughts and recommendations.

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