Ore Reserve Estimation of Saprolite Nickel Using Inverse Distance Method in PIT Block 3A Banggai Area Central Sulawesi

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Abstract. Reserve estimation is one of important work in evaluating a mining project. It is estimation of the quality and quantity of the presence of minerals have economic value. Reserve calculation method plays an important role in determining the efficiency in commercial exploration of a deposit. This study was intended to calculate ore reserves contained in the study area especially Pit Block 3A. Nickel ore reserve was estimated by using detailed exploration data, processing by using Surpac 6.2 by Inverse Distance Weight: Squared Power estimation method. Ore estimation result obtained from 30 drilling data was 76453.5 ton of Saprolite with density of 1.5 ton/m$^3$ and COG (Cut Off Grade) Ni $\geq$ 1.6 %, while overburden data was 112,570.8 tons with waste rock density of 1.2 ton/m$^3$. Stripping Ratio (SR) was 1.47 : 1 smaller than Stripping Ratio (SR) were set of 1.60 : 1.

1. Introduction

1.1 Background

Exploration activities and calculation of mineral deposits reserves constitute an important step in the mining operation plan, so that the quantity and quality of mineral deposits must be known by value of SR (Stripping Ratio) and COG (Cut Of Grade), in order to result high degree of geological confidence and economy. The use of a computerized system in certain Mine Software can calculate the reserves and even design a mine with a faster and better approach to calculating mineral deposits.

Surpac 6.2 is one type of GIS Software (Geologic Information System), the CAD group (Computer Aided Design) which is a software from A Gemcom Software Company Australia. CAD (Computer Aided Design) is software that provides utility to input data, display visualization, and representation in 3 dimensions [1].

PT. Kumala Mining is a contractor of PT. Aneka Nusantara International which is a mining company with nickel ore commodities. This company located in Banggai, Central Sulawesi. The aims of this research are to calculate tonnage reserves of nickel ore deposits, tonnage of overburden, and stripping ratio in the Block PIT 3A. Estimating the reserves and stripping ratio in PIT Block 3A at PT. Kumala Mining Site Project Bunta given limit value of COG (Cut Off Grade): $>$1.6, density of rock: 1.5 ton/m$^3$, waste: 1.2 ton/m$^3$, standard of SR (Stripping Ratio) in company: 1.60 : 1.
2. Basic Theory

2.1 Model Block Method

Block model is one of the existing tool functions in Surpac 6.2, this method effectively used on ore mineral as it uses attributes of content, quality, density, and lithology as consideration of reserve estimation [2].

- **Geological Database (GDB)**
  Store drillhole survey, lithology and quality data, generate standardized summary and customizable reports, and display graphical drillhole data. GDB can display lithology, interval, geophysical and correlation as well as provide the function of compositing and washability.

- **Constraints**
  All block model functions can be done with constraints. Constraint is a logical combination of one or more spatial objects in the selected block. Objects that can be used in constraints are plane surface, DTM, solids (body solids), closed strings and attribute block values. Constraints can be stored in files for reuse and may be used as a component of other constrains.

- **Estimations**
  Once the block model is created and all the required attributes exist, it should then be done with some estimation methods. This can be done by estimating and assigning attribute values from sample data that have XYZ coordinates and the value of the main attribute estimation methods.

2.2 Pit Design

It is one of the applications in Surpac 6.2 for the design of mining pits. Mining pit design is done after getting areas that have a stripping ratio in accordance with the set. These areas are then formed into mining blocks by naming such as Block 01, Block 02, and so on. Each of these blocks is limited by a polygon with different extents [3].

Based on the analysis of the area using the software, the limit of the area of mining (pit limit) and the limits of mining elevation can be determined. Based on the data, it can be done the overall mining pit design and the estimated the reserve that has a stripping ratio that has been determined. In preliminary reserve estimation, it aims to estimate the amount of reserves that can be mined with the appropriate stripping ratio and obtain ore distribution data. The ore distribution is based on quality of laboratory analysis from exploration drilling data [4].

Some stages in pit design using Surpac 6.2 namely: calculation of reserve blocks, field topography identification, making mine layout and design pit, data of bench geometry (high bench, wide bench and tilt bench), and data of road geometry (road width and slope of road) [5].

2.3 Stripping Ratio.

The stripping ratio is defined as the ratio of the of material cover (waste) to the ore material (ore). At ore mines, this ratio is usually expressed in tonnage of waste / tonnage of ore. In coal mines are often used waste/ton of coal [4].

3. Methodology

The research method is to collect accurate data at field is associated with reserve estimation. The research methods include; data collection, data processing, and analysis of data [5].

4. Results and Discussion

4.1 Reserve Calculation Method

To find out the nickel ore reserves contained in the research area of PIT Block 3A, calculated using non-conventional methods that use Surpac 6.2. Firstly, this research is done by making geological database and block model to calculate the area and volume of existing reserves as reference reserves estimates or to determine the value of nickel ore tonnage. COG (Cut Off Grade) in the calculation of reserves in this study determined by the company is 1.6%. The level or stage of exploration conducted
at PIT Block 3A is an advanced stage. The collected data indicates that the level of confidence in reserves is higher.

In the use of Surpac 6.2 Software, the step to make a reserve estimation is to first create a geological database with core drilling data, rock description, and laboratory analysis which further creates and calculates the volume of block model and its function of Constraint with Inverse Distance Weight Power 2 method with previous Geological Database created.

Geological database on the outline is the data that contains the geological information representatives of core drilling (core drilling) exploration, rock description and analysis of the sample in the preparation laboratory. With the geology database we can visualize 30 drilling point in Pit Block 3A, even making a cross-section and shape of nickel ore deposit.

**Figure 1.** Geological database PIT Block 3A.  
**Figure 2.** Shape of nickel ore distribution.

By a pre-prepared geological database, it can created block model. Due to the distribution of laterite nickel deposits located in Pit Block 3A is not uniform then sediment block model required constraint with modify constraint select with functions that can be modified according to the needs with grade and lithology parameter.

First constraint with lithologic attributes will form a block corresponding to lithology, with upper and lower boundary on the saprolite zone only, using the top ore and bottom ore boundary of saprolite zone and the outer boundary of the specified drilling point using the formula, so that the data is estimated only at lithology/geological database of the saprolite zone.

**Figure 3.** A Block without constraints.  
**Figure 4.** Block with grade and lithology constraints.
Both constraint select with this grade attribute will separate the appropriate blocks with the desired grade starting from the lowest grade of 1.6 which is still economical when mined to the highest grade available in accordance with COG (cut off grade).

Next, marked with some color on the block representing a certain grade of ore located in the saprolite zone, then the block with color will separate the blocks according to the lowest grade available in the database that is 1.6 to the highest grade available. It is also intended to separate the visual distribution of the deposit profile according to the color.

![Figure 5. Block with grade constraints based on colours yellow >1.6, green >2.0 and dark green >2.5.](image)

The volume and tonnage calculated by using Inverse Distance Weight Power 2, with density value of 1.5 tons/m\(^3\) and the lowest grade of COG (cut off grade) determined by the company is 1.6. Then the calculation of volume only on the saprolite zone and tonnage will only be calculated starting from the level of >1.6 up. Reserve tonnage is obtained by multiplying the volume of saprolite 50969 m\(^3\) with density ore 1.5 ton/m\(^3\). So that the ore tonnage is 76453.5 tons in accordance with the calculation using Surpac 6.2.

4.2 Design of Pit Mine
The construction of mining bench designs is based on safety factors with geotechnical recommendations by using open pit mining method. Based on the direction of ore distribution. Design of the geometry of the mining bench requires several important parameters, such parameters are: Standard Stripping Ratio (SR) 1.60: 1, height of bench 3 m, width of bench 1.5 m, and single slope 56°.

Construction bench width design that is up to 78,959 mdpl does not change the value of the geotechnical recommendation decisions, but at the elevation of 73,968 mdpl, width of the bench on the pit block design changes as far as 15,534 meters and at elevation of 63,908 md as far as 37,998 meters. This is caused by the uneven distribution of the ore at the elevation. The shape of the pit design on Pit Block 3A can be seen on figure 6.
Based on the factors described above and the consideration of the mining design and recommendations from geotechnical study that the design of Block 3A pit using surpac 6.2 applies the open pit mine system. So in getting the volume from the design of Block 3A pit by using Software Surpac 6.2 is 144778 m$^3$.

![Figure 6. Design of PIT Block 3A in DTM.](image)

**Figure 6.** Design of PIT Block 3A in DTM.

![Figure 7. Of PIT Block 3A in String.](image)

**Figure 7.** Of PIT Block 3A in String.

**4.3 Waste Tonnage/Overburden (OB)**

The calculation of overburden is also done based on the calculation of pit volume. Tonnage overburden is influenced by the extent of pit design results. The overburden tonnage from the pit mine can be calculated by reducing the pit volume, 144778 m$^3$ with the ore volume, which is 50969 m$^3$ and multiplying with the waste rock density of 1.2 m$^3$/ton. So in the tonnage can be over burden pit block 3A is 112570.8 tons.

**4.4 Stripping Ratio (SR) Pit Block 3A**

The determination of the stripping ratio relates to the feasibility of ore deposits in PIT 3A to be mined profitably. The shape of ore and waste deposit illustration can be seen in figure 8. The value of stripping ratio is calculated by comparing the waste tonnage to ore tonnage. Based on the calculation of ore tonnage and waste tonnage, namely:

- Tonnage Ore = 76453.5 tons
- Tonnage Waste = 112570.8 tons

![Figure 8. Modelling of Ore and Waste.](image)

**Figure 8.** Modelling of Ore and Waste.
After the tonnage of waste and tonnage of ore calculated in research area obtained value of SR (stripping ratio), that is 1.47:1. From the value of stripping ratio obtained (1.47:1), it is known that the value of stripping ratio is smaller than the stripping ratio set by the company, which is 1.60: 1. So that the reserves of nickel contained Pit Block 3A is feasible to proceed to phase of mining operations planning and include the category of Inferred Ore Reserve in accordance with the provisions of the Code-KCMI 2011.

5. Conclusion

From the results of the description and discussion in the previous chapters, it can be concluded as follows:
1. Based on the results of the analysis, the volume of ore reserves is 50969 m³ and tonnage of saprolite reserves for PIT Block 3A PT. Kumala Mining Site Project Bunta with 30 drilling points is 76453.5 tons with density of ore 1.5 ton/m³ calculated using Surpac 6.2 with COG (cut off grade) Ni ≥ 1.6%.
2. Based on pit design and some analysis, pit volume is 144778 m³, waste volume is 93809 m³ and tonnage from overburden PIT Block 3A is 112570.8 tons with waste rock density 1.2 m³/ton calculated using Surpac 6.2.
3. Stripping Ratio (SR) of the research area is 1.47: 1. The reserves of nickel deposits contained Blocks 3A are feasible to be mined, because the SR of the study area is smaller than the SR value set by PT. Kumala Mining is 1.60: 1.

References
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