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THE HARMONIZING MINE PLANNING IN THE EAST KALIMANTAN COKING COAL MINE: THE CHALLENGES AND IMPROVEMENTS

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ABSTRAK

The coking coal mine at the research site is in the Pamaluan formation East Kalimantan. The condition of the mine has many complexities and challenges, such as natural slope condition (30º-35º), narrow pit area and low out pit dump capacity limited by land compensation issue, overburden material, geological structure, coal with very thin layers (<1 m) and consist multiple products in a layer, small number of strips and large number of blocks and high SR pit and SR balance in short range.

In mine planning at the research location, many improvements need to be made so that all aspects, starting with mine planning and operations, can run smoothly and profits can be as expected. Some of the improvements that have been made at the mine such as build mine planning concepts, build fleet allocation rules, structural and stratigraphical geology modelling and improve drill & blast plan, implementation dynamic mine planning and optimize mining digital product. By implementing these improvements, significant positive impacts have been achieved, such as Consistently maintain mine planning compliance (accuracy) >97%, Maintain fleet productivity performance in range of 95% - 110%, Consistently achieving production targets >97%, Able to maintain SR balance by achieving weekly coal plan with the range of 94 - 103%, Achieving blasting performance results with a value of >97% and Maintain work safety aspects with no accidents and loss time injury.

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BACKGROUND

The goal of mine planning and design of any coal mining operation is to design an integrated coal exploitation system that will ensure that the coal is extracted and prepared to meet a desired market specification, at a minimum unit cost, within acknowledged safety, health, social, legal and regulatory constraints. A large number of specific engineering, scientific and economic disciplines contribute interactively to the overall mine planning and design process, thus making it a true multi-disciplinary activity (Spearing et al, 2023).

Coal is an organic material that forms in sediments from large volumes of vegetation as they die, regrow (frequently in swamps and wetlands) and are slowly buried over geological time becoming solidified due to increasing temperature and pressure. The swamp location is important as the dead vegetation does not always readily decay as the swamp is typically oxygen deficient, so peat is often formed and then converted to coal over several hundreds of millions of years.

This site location has coking coal commodities in pamaluan formation East Kalimantan, that have unique characteristics that become challenges to mining. This paper shows all the challenges that exist in this coking coal mine and presents improvements by utilizing all aspects of literacy, methods and technology as part of working with these challenges to maintain mining performance.

THE CHALLENGES

The condition of the mine has many complexities and challenges, such as natural slope condition, narrow pit area and low out pit dump capacity limited by land compensation issue, overburden material, geological structure, coal with very thin layers (<1 m) and consist multiple products in a layer, small number of strips and large number of blocks and high SR pit and SR balance in short range.

Natural slope condition

In the pit mining location, the relatively steep natural slope has an average slope of 35–50 degree. This is due to the presence of deposited coal, which is indeed located at the foot of the hill, so it is required to dig the hill to the top to get coal.

Figure 1 shown the 2D section of the natural slope pit condition. With these conditions, challenges have been presented since exploration, where drill data collection is limited by natural slope conditions and continued during land clearing and mining operations, which greatly limit the ability of mining equipment with high slope degree. In addition, the hill also has bumpy hill face, with different conditions in each area.

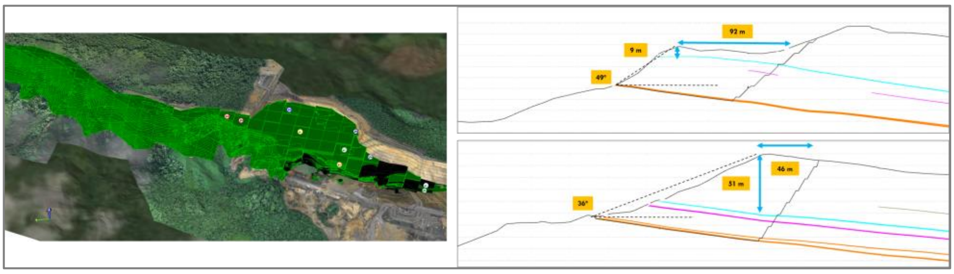

Figure 1. Section 2D natural slope

Narrow pit area and low out pit dump capacity limited by land compensation issue

The pit shell design is significantly influenced by the concession boundary on the west side and the permanent infrastructure area on the north side of the deposit area. The pit shell and concession boundary have a nearest distance between pit boundaries of 90 m and a longest distance of 550 m, and the pit shell and permanent infrastructure area have a distance about 250 m.

With the pit shell surrounded by the concession boundary, this also causes the area that can be used as an out-pit dump (OPD) area to be very limited. Moreover, the remaining area is still reduced by the land area that cannot be acquisitioned. This caused a very limited OPD capacity of only about 4.7 Mbcm, or less than 15% of the total disposal needs.

Overburden Material

The lithologic composition in the mining area is dominated by claystone and sandstone where the percentage of claystone is 65% and sandstone 35%. Claystone material has a unit weight (γ_n) of 16 KN/m3, saturated unit weight (γ_w) 19 KN/m3, cohesion 250 KN/m^2, and friction angle 28°. The sandstone material has a unit weight (γ_n) of 18.1 KN/m3, cohesion of 600 KN/m^2, and friction angle of 32°. Both overburden materials can be categorized as very hard materials for overburden in coal mining areas which has the potential to cause difficult digging due to the hardness of the material.

Especially for sandstone material, it has a unique layering where it also forms lenses layer and pinch out. The sandstone lens layer has thickness from 1 - 4 m and interbedded the claystone layer. This indicates that the depositional environment of this layer is in a distributary channel complex

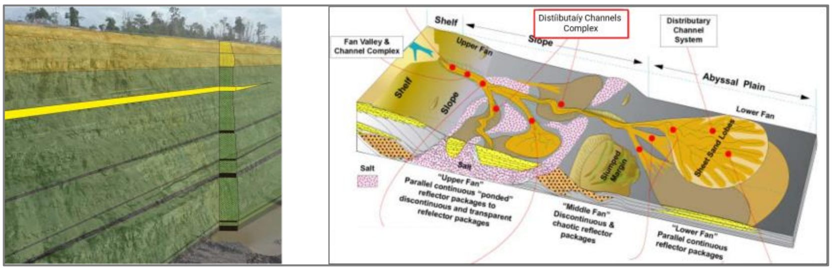

Figure 2. Stratigraphical layer and depositional environment

Geological Structure

There are many geological structures found in the overburden layer in the mining area. Generally, geological structures found in sandstone layers are blocky structures that form blocky joints, gray- brown grain color, with a high number of natural cracks. Sandstone layers that have this structure are found in the upper sandstone layer which is 10 - 15 m thick.

The geological structure is not only a weak layer for the stability of the mine slope, but also become a zone that causes energy loss in blast activity due to reduced gas propagation performance. This is certainly very disadvantages and has the potential to cause poor blasting results and certainly disturb mining operational.

Figure 3. Geological structure in mining area

Coal with very thin layers (<1 m) and consist multiple product in a layer

The number of coal seams found at the mining location is 3 seams, which are (from above) seams B3, B2 and B1. Some of these seams have splitting, such as seam B3 which is being split into seam B3U and seam B3L, and seam B1 which is being split into seam B1U and seam B1L. The coal thickness (cumulative) of seam B3 is around 0.5 - 1.0 m, B2 is around 0.3 - 0.5 m and seam B1 is around 0.5 - 1.0 m.

The determination of the type of coal product has previously been determined by the concession owner, which is generally classified into high sulphur products and low suphur products. Coal that includes high sulphur products is found in seam B1 and those that include low sulphur products are found in seams B3 and B2. The low sulphur product itself is re-divided into 4 more products according to the characteristics of the low sulphur product coal sub-layer (refer to actual coal profile that exposed).

Small number of strips and large number of blocks

The pit shell of this pit has a unique geometry. The pit has 3.83 km long following the strike and only has an average width of 0.24 km following the down-dip. This results in pit conditions that have a small number of strips (average 4 strips) and a large number of blocks (65 blocks). Moreover, there is an anomalous strip number area where the strip number is twice as many strip numbers as other areas (Figure 4).

The number of strips and blocks will greatly affect the concept of mine planning that will be applied and affect the area of openings that can become the equipment work plan area in the pit. especially in the anomaly area that described above, it needs a mature concept in the mining process in that area.

High SR pit and SR balance in short range

The stripping ratio is an important measurement related to the open-pit mining process. Put simply, it represents the amount of waste material, also known as overburden, that must be moved in order to extract a given number of ore or coal. That said, stripping ratios are not only about the volume of unwanted material present at a site; they also consider the types of material that must be removed to reach the ore or coal.

The LOM pit has an SR of 24.35, which by definition requires digging 24.35 bcm of overburden to obtain 1 ton of coal. If divided per seam, seam B3 has an OB thickness of 30 – 45 m with a coal thickness of 0.5–1.0 m, so the average SR of seam B3 is 40–65 m. Seam B2 has an OB thickness of 3 – 8 m and a coal thickness of 0.3 – 0.5 m, so the average SR of seam B2 is 15 – 24. Seam B1 has an OB thickness of 6 – 14 m and a coal thickness of 0.6 – 1.0 m, so the average SR of seam B1 is 14 – 24 m.

The figure 4 shown the resgraphic map that shows the color gradation of the SR of each block, where the red colored blocks are blocks that have an SR of more than 25 and the yellow, green and blue colored blocks are blocks that have an SR of less than 25. One of the most difficult challenges in this pit is to maintain the SR balance in the short-range plan while still referring to the SR of the pit shell (LOM) with variations from the SR of each block and each seam that needs to be opened.

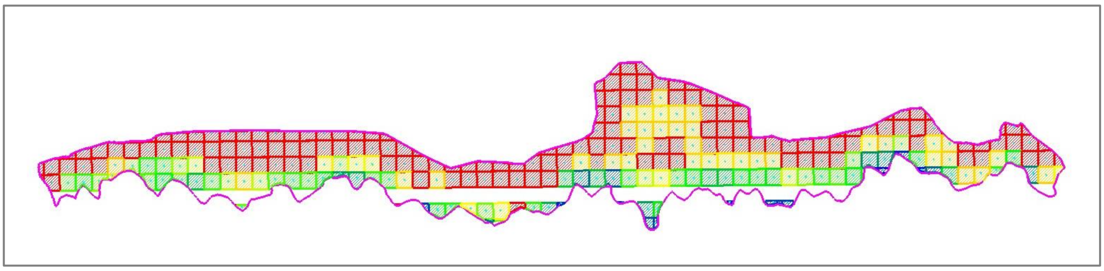

Figure 4. Block-strip and resgraphic

THE IMPROVEMENTS

In mine planning at the research location, many improvements need to be made so that all aspects, starting with mine planning and operations, can run smoothly and profits can be as expected. Some of the improvements that have been made at the mine such as build mine planning concepts, build fleet allocation rules, structural and stratigraphical geology modelling and improve drill & blast plan, implementation dynamic mine planning and optimize mining digital product.

Build Mine Planning Concept

With so many challenges in the mining area, one of the improvements made is to build a mine planning concept. Mine planning concept is made to overcome some of the challenges described in section B. The mine planning concept consists of access concept, horizon definition and sequence concept.

This access concept is driven by the absence of a final ramp in the pit due to the pit shell conditions described above. This access concept fulfills the access needs in the pit and the waste dump area. There are several rules that are made with their respective functions where the rules need to be made for each mining plan period (Figure 5). The rules in this access concept are as follows :

1. Rule 1: Construct lowwall access along the lowwall pit. The purpose of this rule is to create access along the lowwall as access from pit to disposal due to no final access at the highwall.
2. Rule 2: Construct access for each coal seam. The purpose of this rule is to create access to expose each coal seam and coal getting access. For the coal, B1 access is an access that was constructed in the previous period and follows Rule 3.

3. Rule 3: Construct access from the lowwall to the highwall that is located at the free face. The purpose of this rule is to create access from the highwall as access from pit to disposal, support the development of near-exposure areas, initiate access to construct access to each seam for the next period, and connect to the cropline coal B3 area.
4. Rule 4: Create source coal areas, near-exposure areas, and development areas. The purpose of this rule is to create a wide area for source coal, flip-flop expose, and coal getting, create a near-exposure area with pre-strip to minimize expose time, or accelerate the source coal area for the next period.
5. Rule 5: Create and initiate access at the forehill. The purpose of this rule is to initiate access using a small fleet that is constructed from lowwall or highwall (as a condition) and as access for the next period. Stripping activity after this access is constructed has two directions: follows block and reverse block.
6. Rule 6: Construct access from previous initiated access at the forehill. The purpose of this rule is to construct secondary main access from previous initiated access as access from pit to disposal (potentially reducing distance).

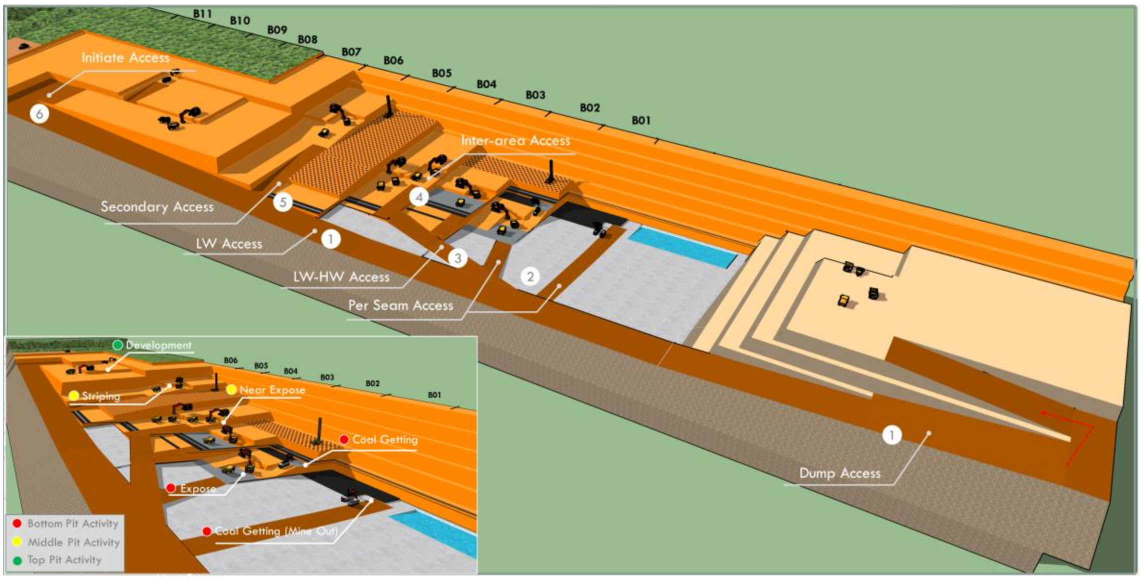

Figure 5. The several rules of access concept

The horizon definition has the intention of dividing the equipment/fleet work area into several parts according to the layer and its purpose. This has the aim of facilitating the placement of tools for sequence continuity in order to achieve production targets in accordance with the mine plan. The parts of the horizon definition are as follows:

1. Stripping area is an area that is above the near expose area and aims to prepare the near expose area in the next period.
2. Near expose area, is an area above the expose area with a thickness range of 4 - 8 m and aims to prepare the expose area in the next period.
3. Expose area, is an area above the coal seam with a thickness of 3 m and aims to prepare the coal expose in the next period.

Figure 6. The horizon definition

The block mining concept is the name given to the sequence concept implemented at this mine. The block mining concept sets the mine progress in the direction of the block or in the direction of the strike where each activity has been planned in such a way as to follow the continuity of the process in accordance with the horizon definition and implement the access concept that must be constructed in each period of the mine plan (Figure 7). The block size used is 60 x 60 m which has also been previously considered to be able to synchronize with the block mining concept that was created. This block mining concept is the answer to the existing challenges where there are a large number of blocks and small number of strips.

The block mining concept is a solution for the continuity of all mining activities, especially the availability of coal inventory and maintaining SR balance, as explained earlier that this pit has a high SR with SR variations in each coal seam, and with a coal profile of thin coal that has several products.

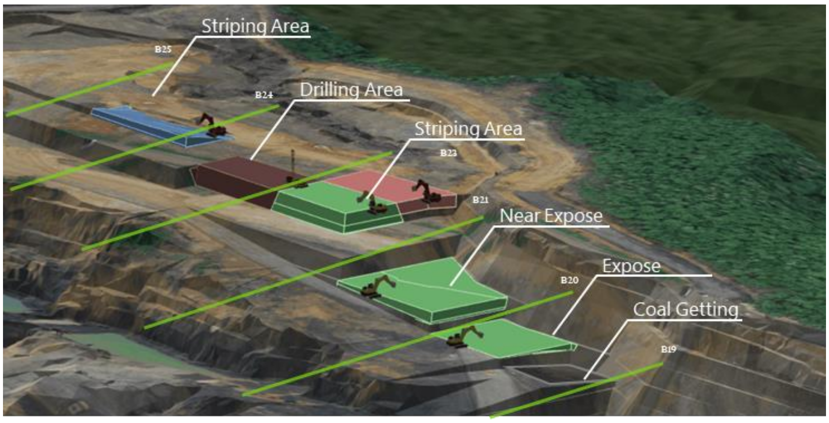

Figure 7. The block mining concept

Build Fleet Allocation Rules

The SR balance in the short range is one of the challenges that requires some improvement to be solved. The fleet allocation rule is a rule to determine the allocation of the fleet number and deployment of OB fleet and coal fleet based on the coal block requirement. The coal block requirement is a rule for the coal block area that must be opened in accordance with the coal seam that is planned to be opened based on the coal target that must be achieved every day. The coal block requirement can be changed according to the coal target that must be achieved and the combination of coal seams opened.

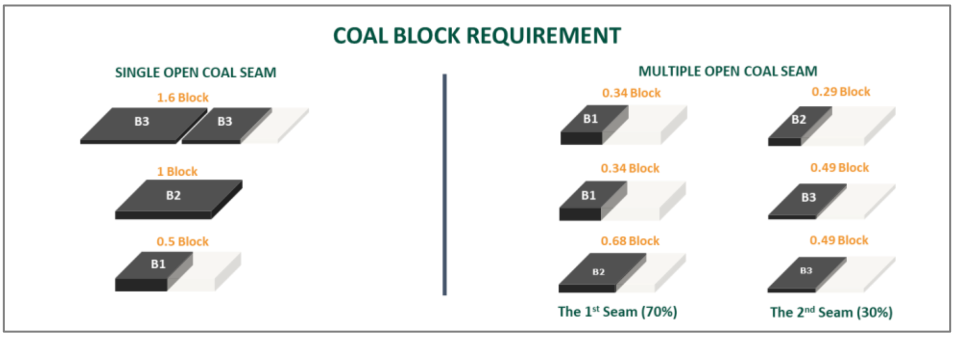

Figure 8. The coal block requirement

Figure 8 describes an example of the coal block requirement with a daily coal target of 2,350 tons with coal thickness profile seam B1 1.0 m, B2 0.5 m and B3 0.3 m. The figure also describes simulations with a single open coal seam or with multiple open coal seams (with several combinations) assuming the 1st seam composition is 70% and the 2nd seam composition is 30% or can follow equation 1.

$$Coal\ block\ requirement = \frac{Daily\ coal\ target\ (ton)}{Coal\ tonnage\ per\ block\ by\ seam\ (ton)}$$

Equation 1. Coal Block Requirement Calculation

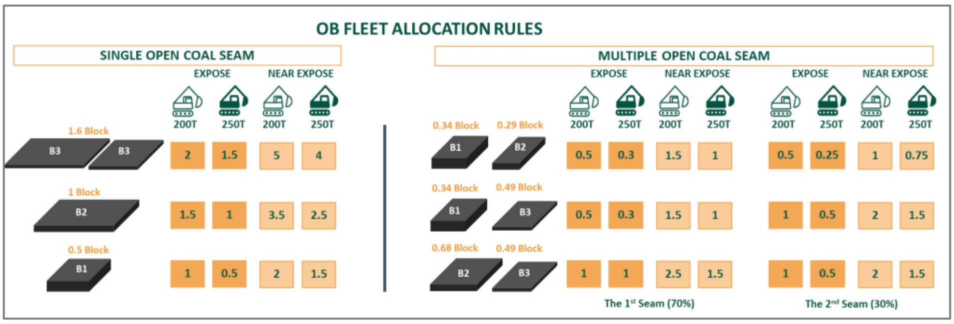

Figure 9. The OB fleet allocation rules

From the coal block requirement above, the OB fleet allocation rules can be created as shown in Figure 9. It should be highlighted that the OB fleet allocation rules only set the number of fleets in the expose and near expose areas and the remaining fleets are in the stripping area. OB fleet allocation rules also consider simulations with a single open coal seam or with multiple open coal seams as simulated in Figure 8. The number of fleets required is daily (as coal range target) and if it remains, it can move to another horizon with available area.

To determine OB fleet allocation, equation 2 used to calculate it, with calculate number of OB requirements of a horizon (block size requirement multiplied by thickness of horizon) divided by OB fleet capacity per day

$$OB\ fleet\ allocation = \frac{\Sigma\ OB\ requiremet\ of\ a\ horizon\ (bcm)}{OB\ fleet\ capacity\ per\ day\ (bcm)}$$

Equation 2. OB Fleet Allocation

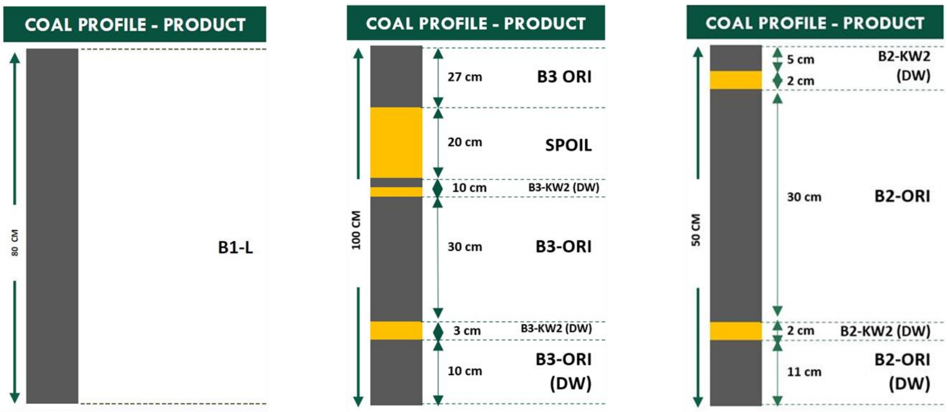

Figure 10. The example of coal profile with multiple products

The allocation of the number of fleets in the coal fleet allocation rules depends on the simulation with a single open coal seam or with multiple open coal seams (with several combinations). The need for coal fleet allocation is also based on the coal getting process which is in accordance with the number of products produced based on the coal profile. Figure 10 shows an example of a coal profile with multiple products in an area, and it should be known that each area has its own characteristics so that coal profile mapping is carried out every time there is open coal. And in figure 11 shows the coal fleet allocation rules in accordance with the simulation in figure 8 with the type of fleet used is a 30 ton class excavator.

$$Coal\ fleet\ allocation = \frac{Coal\ tonnage\ by\ block\ requirement\ (ton)}{Coal\ handling\ capacity\ a\ fleet\ per\ day\ \ (ton)}$$

Equation 2. OB Fleet Allocation

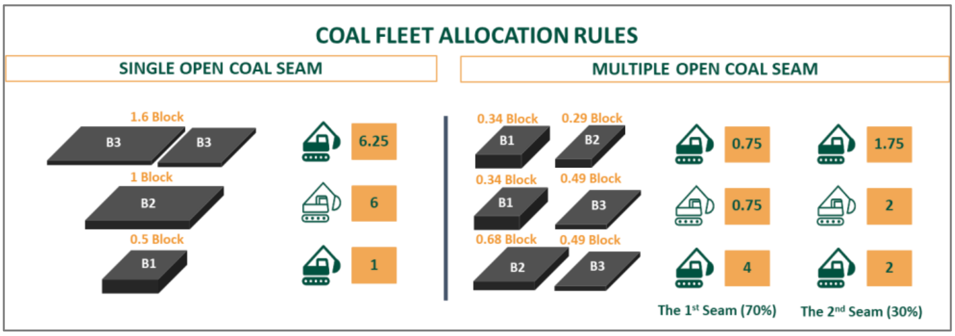

Figure 11. The coal fleet allocation rules

Structural and Stratigraphical Geology Modelling and Improve Drill & Blast Plan

The lithologic composition of the mining area is dominated by claystone and sandstone where the percentage of claystone is 65% and sandstone is 35%. The overburden is also layered and there are layers of lenses and pinch outs that have a thickness of 1 - 4 m and interspersed with layers of claystone. In addition, the geological structure that is commonly found is a blocky structure that forms a blocky joint with a high number of natural cracks. Natural cracks found in these layers become a zone of weakness that causes energy loss in blasting activities which creates the potential for poor fragmentation. The poor fragmentation is also potentially caused by the variation of overburden layers that have their own characteristics and strength, so that the blasting energy delivery is not optimal.

The improvement made to solve the 2 challenges above is modeling the geological structure to know the direction of the structure and modeling the whole overburden rock layer. In the collectivity of the structural geology data, the joint orientation in overburden layer has a strike-dip of N 355º E/ 23º (Figure 12).

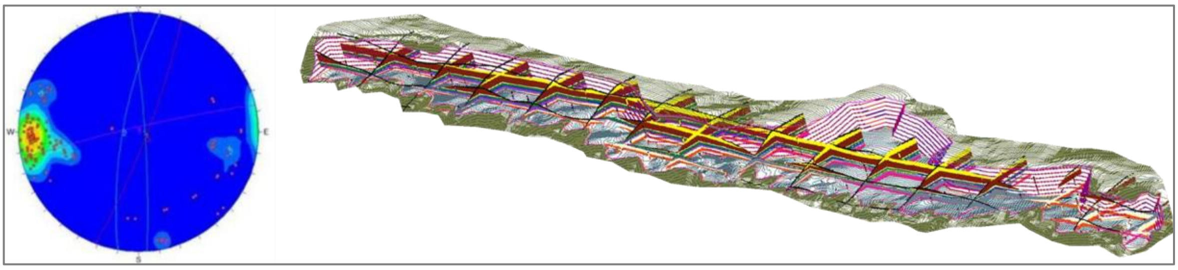

Figure 12. Structural and stratigraphical geology modelling result

The stratigraphical geology modeling was limited by the missing drill data excluding coal seams data. Therefore, the data used uses actual outcrops that have been exposed and interpolated in strike and dip, as well as correlation with outcrops that are exposed as the mine progresses. The stratigraphy modeling data will then be used as a guideline in improving the drilling and blasting plan to conform to the characteristics of the layers to be worked on. Figure 13 shows an example of improving the drill and blast plan when the area consists of multiple stratigraphic layers, with the option of working on each layer or working simultaneously by adjusting the position on the blast column profile. Figure 14 shows an improved blast plan by considering geological structure data collected from collecting data, the key point is that the direction of blasting energy should not be in the same direction or against the direction of the geological structure so as not to cause energy loss that has the potential to cause poor fragmentation.

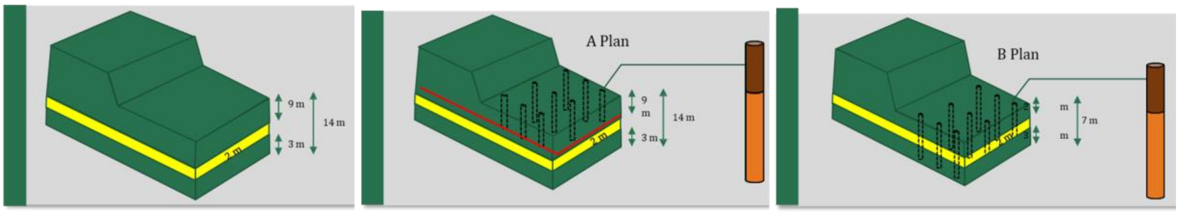

Figure 13. Improving drill and blast plan follows stratigraphical data

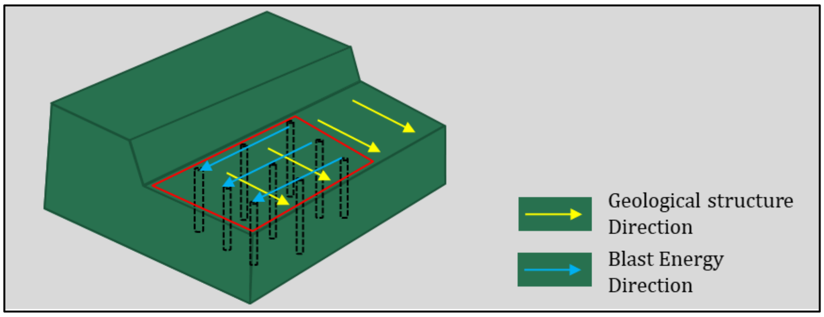

Figure 14. Improving blast plan by considering geological structure data

Implementation Dynamic Mine Planning and Review

The mine plan can be categorized as one of the things that are dynamic. In this meaning, the mine plan can be changed according to the conditions. The dynamic mine planning is a flexibility to the mine plan if it needs to be changed and dynamically adjust other strategies to achieve the target. This is very dependent on the parameters that have been used as guidance in the previous mine plan having changed by the time the mine plan is implemented. Many factors can influence this, such as variations in geological models, equipment conditions, material conditions, changes in focus concerns and others.

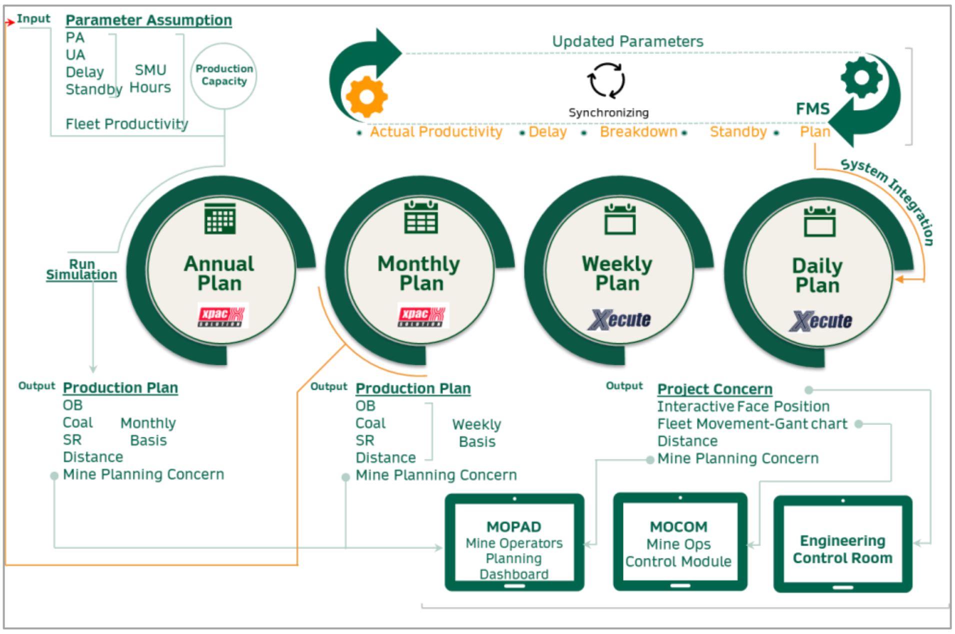

Figure 15. Cycle of integration and dynamic mine planning

Figure 15 shows the cycle of integration and dynamic mine planning implemented in this mine. The periods of the mine plan are strongly integrated and interrelated with each other, starting from the annual plan, monthly plan, weekly plan to the daily plan. If one of the plans changes, the other plans will be adjust to the changes. And if in the process of implementing a mine plan there are parameters that change, dynamic mine planning needs to be implemented by re-sequencing the mine plan so that it continues to achieve the previously determined targets, maintain good performance and maintain the accuracy of mine planning compliance.

In terms of implementing dynamic mine planning, the review of the plan is consistently made from shift to shift, day to day, week to week and so on. This is a key consideration for dynamic mine planning. Figure 16 shows an example of several review of a previous plan.

Figure 16. Example of several review of previous plan

Optimize Mining Digital Product

In the current era, the use of digital technology can be found in all aspects including the mining industry. The digital technology can simplify work in mining activities and provide effectiveness and efficiency in the process. In this mine, there are several mining digital products that are implemented and have each function in support mine planning and operational process that are integrated with each other, such as :

1. MinervaApps (MineApps)
2. Mine operation control module (MOCOM)
3. Mine operation planning dashboard (MOPAD)
4. Integrated water management (IWM)
5. Augmented Reality (AR)
6. Integrated fleet management system (FMS)
7. Fuel and road analyzer dashboard (FRA)
8. Effective validation attendance (EVA)
9. Real-time geotechnical monitoring (Radar) and dashboard
10. Live CCTV mine area
11. LiDAR drone surveying
12. Drill high precision system (HPS)
13. Asset resources management system (ARMS)
14. SHE mobile apps (SHEPRO)

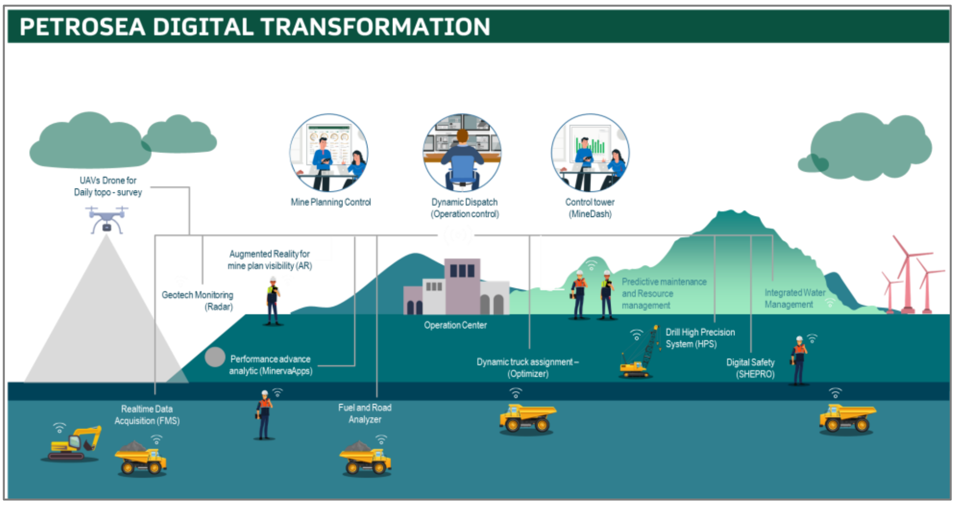

Figure 17. Integrated mining digital product

RESULT AND SUMMARY

By implementing these improvements and work together with all challenges, significant positive impacts have been achieved, such as:

1. Consistently maintain mine planning compliance (accuracy) >97%.
2. Maintain fleet productivity performance in range of 95% - 110%.
3. Achieving blasting performance results with a value of >97%.
4. Consistently achieving production targets >96%.

5. Able to maintain SR balance by achieving weekly coal plan with the range of 94 - 103%.
6. Maintain work safety aspects with no accidents and loss time injury.

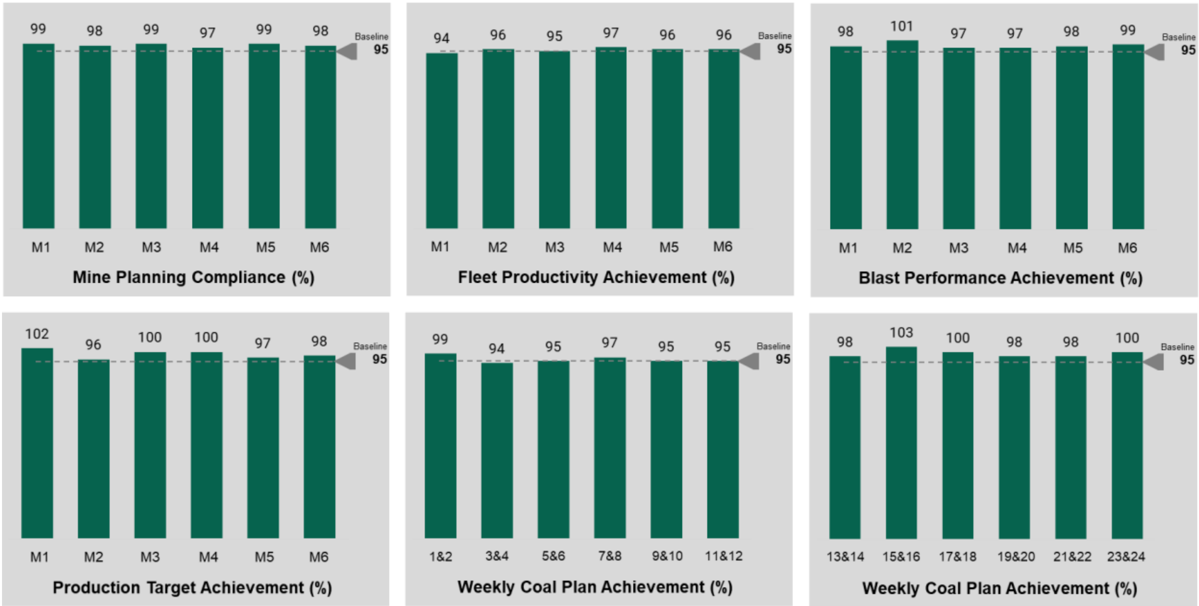

Figure 18. Performance result graph

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BIBLIOGRAPHY

Given, I.A., Cummins, A.B., and Hartman, H.L. (1992) : *Mining Engineering Handbook*. Society for Mining, Metallurgy, and Exploration, Inc : Colorado.

Hartman, H.L., and Mutmansky, J.M. (2000) : *Introductory Mining Engineering*. Jhon Wiley and Sons Inc : New Jersey.

Hustrulid, W., Kuctha, M., and Martin R. (2006). *Open Pit Mine Planning and Design Volume 1- Fubdamentals 3rd Edition*. Taylor & Francis Group : London.

Mazumder, B. (2012). *Coal science and engineering.* Woodhead Publishing India Pvt. Ltd.: New Delhi.

Society for Mining, Metallurgy, and Exploration, Inc. (2023) : *Modern American coal mining : method and applications*. Society for Mining, Metallurgy, and Exploration, Inc : Colorado.

Spearing, A.J.S., Ma, Liqiang., and Ma, Cong-an. (2023) : *Mine design, planning and sustainable exploitation in the digital age*. CRC Press : Leiden.

Supriatna, S., Sukardi R., Rustandi E. (1995) : *Peta Geologi Lembar Samarinda, Kalimantam Timur*. Pusat Penelitian dan Pengembangan Geologi : Bandung.