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Development Mine Scheduling Concept in Making Pit Design

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Abstract

Planning a modern open pit mine requires a computer model of the resources and reserves to be mined, both block and grid models. With current technological developments and has entered almost all sectors including the mining sector, as for computer program packages (software) used by the mining industry, namely Microsoft excel, Mincom minescap and others. An evaluation and analysis system of mine plans/ mine schedules is necessary to make predictions of mining operations that will be carried out and can be used to find the cause of deviation or design deviations. There are several weaknesses in making scheduling manually, so scheduling is done using SPRY which is very helpful in the scheduling process.

Keywords
Mine Scheduling, Manually Scheduling, SPRY

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INTRODUCTION

The planning of a modern open pit mine requires a computer model of the resources and reserves to be mined, either in the form of block or gridded models. With current technological developments that have entered almost all sectors including the mining sector, the computer program packages (software) used by the mining industry, namely Microsoft Excel, Mincom Minescape, etc. The study of mining stages is a part of planning a mining project, because it involves technical and economic aspects of a mining project[1]–[4]. The technical aspects include the technical design of the mining method, the need for main and supporting equipment, while the economic aspects include production and operating costs. In order for the mining process to achieve its goals, it is necessary to design a mining sequence for optimum mining.

Several factors are lacking in making scheduling using the manual method, namely: the preliminary design made by the customer is often not in accordance with the actual progress conditions in the field, in response to design problems and production targets, the customer is more focused on the value of the stripping ratio in accordance with the budget reference fixed yearly,

Mine Scheduling concept can have a very large impact on mining systems and patterns, and mining sequences. which is made using basic calculations based on Super Shovel (total fleet) productivity which will actually be difficult to implement, because the application does not consider the issue of fleet numbers and allocation placement of units with very limited working faces[5]–[7].

By developing the mine schedule concept, it is hoped that:

a. Can estimate the possibility of occurrence of irregularities or deviations earlier.
b. The results of the evaluation can be input both internally and externally to the customer to reach common ground in determining the ideal production plan and targets for both parties.
c. Provide suggestions for design changes and scheduling concepts that are adapted to the actual progress condition approach in the field.

Location

Location study in Pits X at PT XYZ in Kalimantan. data that observed at the research location is the data on blasting activity (blast hole depth, stemming, powder factor, and fragmentation explosion) and activity loading material blasting with method load and device excavation (time excavation and cycle time)[8].

Table 1. Activity observation data detonation and fragmentation of explosives

No	Blok Peledakan	Waktu Pengalian	Waktu Siklus (s)
1	SOS_695A	8	20
2	SOS_695C	8	20
3	SOS_695E	7	16
4	SOS_700A	6	16
5	SOS_700D	8	19
6	SOS_705E	7	17
7	SOS_710H	8	18
	Average	7	18

Retrieval of blasting data is carried out at the beginning of the shift in each blasting block, then proceed with loading and unloading data collection of loading and unloading equipment in blasting blocks that have been observed previously. So from Table 1 it can be seen that the average size of boulder-sized detonation fragmentation (> 50 cm) is 7.46%, with excavation times and cycle times of 7 seconds and 18 seconds.

Mine Design

Mine planning is a technical activity used to achieve the desired goals and objectives. Therefore, in a planning activity there are technical requirements to achieve very important activity goals and objectives as well as the technical sequence of their implementation. In addition, planning activities are ideas or ideas that appear before the activity takes place. From this plan, it can determine what activities and why must be carried out, by whom, when, where and how to carry them out.

Mine planning is paying for the technical requirements of executing firing activities and winning technical sequences for their execution to achieve objectives and activities. Meanwhile, design is part of mine planning that relates directly to geometric aspects, including mining deadlines, mining stages, and production scheduling [9].

From the definition of mine design *(mine design)* above, there are several meanings, namely:

a. The final mining limit is the mining final limit that is still geotechnically permitted and does not exceed the IUP limit with a certain slope and slope angle [10].
b. The stages of mining progress are the forms of mining in a certain time unit that indicate how a hole will be mined from the starting point of mining to the end of mining. The direction of mine progress in the coal seam starts from the outcrop area in a direction perpendicular to the stroke of the seam to the final slope of the mine.

Mine Schedule

Mine scheduling is one part of mine planning. The main goal of scheduling is to get as much profit as possible. Production scheduling is made with the aim of determining the most optimal profit by determining production arrangements per certain time period. Making production scheduling is done conventionally by trial and error, namely by making various production scheduling scenarios and then choosing the most profitable scenario based on the present value of money [9].

Sequences

Sequences are mining shapes (minable geometries) that indicate how a pit will be mined, from the initial entry point to the final pit shape. Other names are expansions, phases, working pit, slices [11]. The general objective of mining sequences is to divide the entire volume in the pit into smaller planning units that are easy to handle. Mining sequences that are well planned will make it easier to design very complex mines. In planning a mining sequence, there are several factors that need to be considered such as geological, geotechnical, heavy equipment used, production scheduling, mining pit design, disposal and drainage plans. By knowing the influencing factors, the planned mining stages will run well. Properly designed mining stages will provide access to all work areas and provide sufficient work space for the operation of mining work equipment.

Mechanism for Making Mine Design and Mine Schedule

The mechanism for making *mine design* and *mine schedule* as a whole can be seen in Figure 1. Based on Figure 1 it can be explained the mechanism for making the first *mine design* and *mine schedule* is *preliminary (yearly)* provided by *mine consultancy*, the design made by mine consultants is often not in accordance with actual conditions in the field. Usually caused by a design made using outdated progress data. The second stage is after the design is received by the customer, the engineering customer makes a quarter design pattern and the concept of a *mine schedule* then distributes it directly to the contractor.

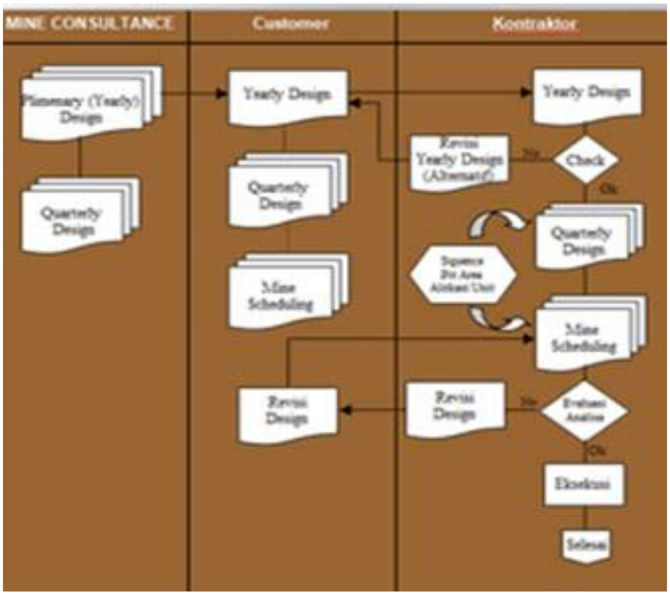

Figure 1. Manufacturing Mechanism Mine Design and Mine Schedule

The third stage, namely the design concept and mine planning from the customer's engineering is checked and studied by the engineering contractor, if there are irregularities, the engineering contractor immediately provides information to the customer and makes an alternative design as input material to make a design revision that will be made by the customer. After the yearly design revision has been completed and declared feasible, the engineering contractor will make a quarterly design and mine scheduling concept. Furthermore, the progress of the mine scheduling is evaluated continuously on a monthly basis *(cross section)* progress and will be *re-scheduled* (calculations are reset) every three months *(quarterly).*

The evaluation system and the concept of *mine scheduling* can be seen in Figure 2 below:

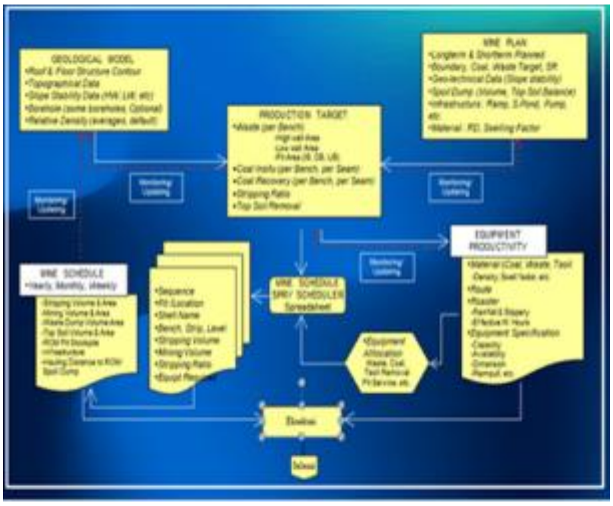

Figure 2. Evaluation System and Mine scheduling concept

Sequence of Data Mine Scheduling Preparation Process

(1) Minescape

The standard format for calculating reserves using Minescape software. It is used to calculatewaste volume, insitu rock mass, coal recovery, coal quality and so on[12]. In calculating the mine reserve calculation, this is carried out jointly between the engineering contractor and the customer. Figure 3 and Figure 4 shows the Minescape workspace.

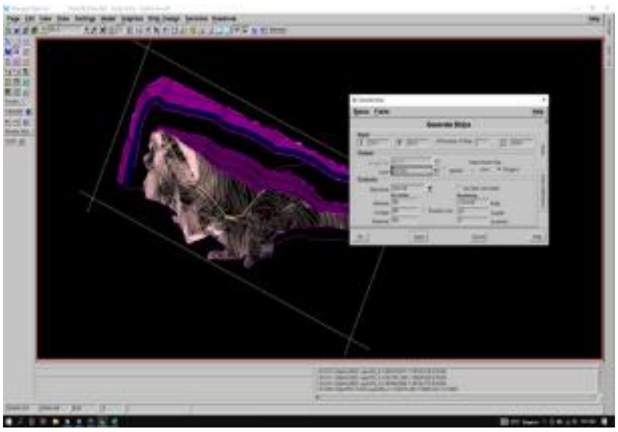

Figure 3. Making blocks strips and reserve polygons

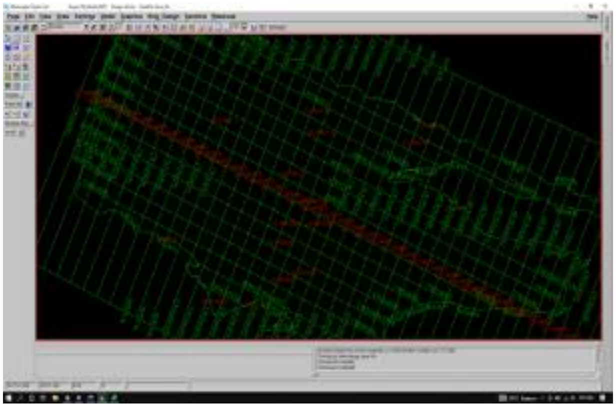

Figure 4. Block Making Strips and Reserve Polygons

(2) Excel

Figure 5, Figure 6 and Figure 7 show reformat using excel (pivot table). Making table reserves based on block shell and level for sections A, B & C (table waste, coal, quality are made separately). Data from minescape after calculating coal reserve recovery is made in the format of mine scheduling (pivot table).

1	NAME	SUBNA	PIT	BLOCK	STRIP	BENCH	SUBNA	SEAM	TOTALV	INTRRN	INTLOS	TOTBUI	OB	COAL
2	ABS_B09S	ABS_B09S	A	B09	S26	P092	BLASTED	UNASSIGN	150.099	0	0	150.099	150.099	0
4	ABS_B09S	ABS_B09S	A	B09	S26	P096	BLASTED	UNASSIGN	548.4387	0	0	548.4387	548.4387	0
7	ABS_B09S	ABS_B09S	A	B09	S26	P100	BLASTED	UNASSIGN	485.0324	0	0	485.0324	485.0324	0
10	ABS_B09S	ABS_B09S	A	B09	S26	P104	BLASTED	UNASSIGN	5.525658	0	0	5.525658	5.525658	0
14	ABS_B09S	ABS_B09S	A	B09	S27	P092	BLASTED	UNASSIGN	398.9932	0	0	398.9932	398.9932	0
15	ABS_B09S	ABS_B09S	A	B09	S27	P096	BLASTED	UNASSIGN	1298.215	0	0	1298.215	1298.215	0
16	ABS_B09S	ABS_B09S	A	B09	S27	P100	BLASTED	UNASSIGN	1150.981	0	0	1150.981	1150.981	0
19	ABS_B09S	ABS_B09S	A	B09	S27	P104	BLASTED	UNASSIGN	15.89615	0	0	15.89615	15.89615	0
23	ABS_B09S	ABS_B09S	A	B09	S28	P092	BLASTED	UNASSIGN	49.19551	0	0	49.19551	49.19551	0
24	ABS_B09S	ABS_B09S	A	B09	S28	P096	BLASTED	UNASSIGN	576.5353	0	0	576.5353	576.5353	0
25	ABS_B09S	ABS_B09S	A	B09	S28	P100	BLASTED	UNASSIGN	1547.527	0	0	1547.527	1547.527	0
27	ABS_B09S	ABS_B09S	A	B09	S28	P104	BLASTED	UNASSIGN	1816.017	0	0	1816.017	1816.017	0
30	ABS_B09S	ABS_B09S	A	B09	S28	P108	BLASTED	UNASSIGN	473.4373	0	0	473.4373	473.4373	0
35	ABS_B09S	ABS_B09S	A	B09	S29	P096	BLASTED	UNASSIGN	8.226783	0	0	8.226783	8.226783	0
36	ABS_B09S	ABS_B09S	A	B09	S29	P100	BLASTED	UNASSIGN	176.4946	0	0	176.4946	176.4946	0

Figure 5. Edit input excel reserve

YEAR	MONTH	PC 2000 \PA	PC 2000 \UA	PC 2000 \RATE	PC 1250 \PA	PC 1250 \UA	PC 1250 \RATE	CAT 395D \PA	CAT 395D \UA	CAT 395D \RATE	SL 500 \PA	SL 500 \UA	SL 500 \RATE	PC 400 \PA	PC 400 \UA	PC 400 \RATE	PC 200 \PA	PC 200 \UA	PC 200 \RATE
2022	OCTOBER	88%	71%	825	88%	72%	525	88%	72%	450	89%	72%	350	89%	72%	250	92%	72%	150
2022	NOVEMBER	88%	69%	825	88%	70%	525	88%	70%	450	89%	70%	350	89%	70%	250	92%	70%	150
2022	DECEMBER	88%	65%	825	88%	66%	525	87%	66%	450	89%	66%	350	89%	66%	250	92%	66%	150
2023	JANUARY	88%	63%	825	88%	63%	525	87%	63%	450	89%	62%	350	89%	62%	250	92%	63%	150
2023	FEBRUARY	88%	73%	825	88%	73%	525	87%	73%	450	89%	71%	350	89%	71%	250	92%	72%	150
2023	MARCH	88%	67%	825	87%	66%	525	87%	66%	450	89%	65%	350	89%	65%	250	92%	67%	150
2023	APRIL	88%	62%	825	87%	61%	525	87%	61%	450	89%	61%	350	89%	61%	250	92%	62%	150
2023	MAY	87%	72%	825	87%	72%	525	87%	72%	450	89%	71%	350	89%	71%	250	92%	72%	150
2023	JUNE	88%	70%	825	87%	69%	525	87%	70%	450	89%	69%	350	89%	69%	250	92%	70%	150
2023	JULY	88%	71%	825	87%	71%	525	87%	71%	450	89%	70%	350	89%	70%	250	92%	71%	150
2023	AUGUST	88%	71%	825	88%	70%	525	87%	70%	450	89%	69%	350	89%	69%	250	92%	70%	150
2023	SEPTEMBER	88%	73%	825	88%	73%	525	87%	73%	450	89%	72%	350	89%	72%	250	92%	73%	150
2023	OCTOBER	88%	71%	825	88%	71%	525	87%	71%	450	89%	70%	350	89%	70%	250	92%	71%	150
2023	NOVEMBER	88%	69%	825	88%	68%	525	87%	68%	450	89%	67%	350	89%	67%	250	92%	68%	150
2023	DECEMBER	88%	66%	825	87%	65%	525	87%	65%	450	89%	64%	350	89%	64%	250	92%	66%	150

Figure 6. Edit input excel reserve

YEAR	MONTH	PC 2000 \PA	PC 2000 \UA	PC 2000 \RATE	PC 1250 \PA	PC 1250 \UA	PC 1250 \RATE	CAT 395D \PA	CAT 395D \UA	CAT 395D \RATE	SL 500 \PA	SL 500 \UA	SL 500 \RATE	PC 400 \PA	PC 400 \UA	PC 400 \RATE	PC 200 \PA	PC 200 \UA	PC 200 \RATE
2022	OCTOBER	88%	71%	825	88%	72%	525	88%	72%	450	89%	72%	350	89%	72%	250	92%	72%	150
2022	NOVEMBER	88%	69%	825	88%	70%	525	88%	70%	450	89%	70%	350	89%	70%	250	92%	70%	150
2022	DECEMBER	88%	65%	825	88%	66%	525	87%	66%	450	89%	66%	350	89%	66%	250	92%	66%	150
2023	JANUARY	88%	63%	825	88%	63%	525	87%	63%	450	89%	62%	350	89%	62%	250	92%	63%	150
2023	FEBRUARY	88%	73%	825	88%	73%	525	87%	73%	450	89%	71%	350	89%	71%	250	92%	72%	150
2023	MARCH	88%	67%	825	87%	66%	525	87%	66%	450	89%	65%	350	89%	65%	250	92%	67%	150
2023	APRIL	88%	62%	825	87%	61%	525	87%	61%	450	89%	61%	350	89%	61%	250	92%	62%	150
2023	MAY	87%	72%	825	87%	72%	525	87%	72%	450	89%	71%	350	89%	71%	250	92%	72%	150
2023	JUNE	88%	70%	825	87%	69%	525	87%	70%	450	89%	69%	350	89%	69%	250	92%	70%	150
2023	JULY	88%	71%	825	87%	71%	525	87%	71%	450	89%	70%	350	89%	70%	250	92%	71%	150
2023	AUGUST	88%	71%	825	88%	70%	525	87%	70%	450	89%	69%	350	89%	69%	250	92%	70%	150
2023	SEPTEMBER	88%	73%	825	88%	73%	525	87%	73%	450	89%	72%	350	89%	72%	250	92%	73%	150
2023	OCTOBER	88%	71%	825	88%	71%	525	87%	71%	450	89%	70%	350	89%	70%	250	92%	71%	150
2023	NOVEMBER	88%	69%	825	88%	68%	525	87%	68%	450	89%	67%	350	89%	67%	250	92%	68%	150
2023	DECEMBER	88%	66%	825	87%	65%	525	87%	65%	450	89%	64%	350	89%	64%	250	92%	66%	150

Figure 7. Import Input Reserve and Calendar Excel to SPRY

(3) Scheduling Setting

Schedule simulations are carried out using mine sequences, namely the numbering of block shell sequences monthly or quarterly, or using equipment settings, which are adjusted according to the shell volume sequence (monthly). Figure 8 shows the Sequence Solids Scheduling by SPRY.

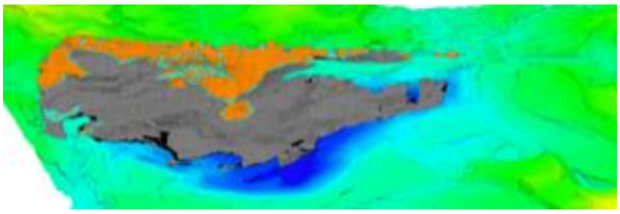

Figure 8. Sequence Solids Scheduling by SPRY

The results of data reformation from the pivot tale are copied and pasted into the case program mine schedule.

(4) Scheduling Updating

Rescheduling is carried out every 3 months (quarterly), with the last month's progress survey database. Figure 9 and Figure 10 shows the SPRY quarterly and the outputs.

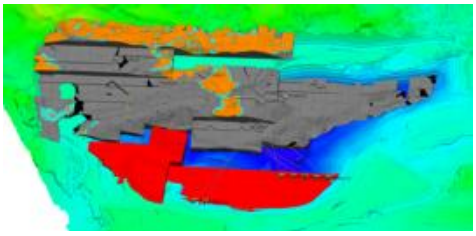

Figure 9. Face position quarterly 1 by SPRY scheduler

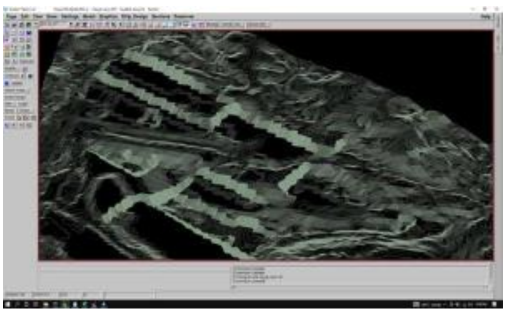

Figure 10. SPRY outputs

RESEARCH METHOD

In this study, it uses a type of quantitative research that refers to applied research. According to Sugiyono[13], quantitative research method is a research method based on concrete data, research data in the form of numbers that will be measured using statistics as a calculation test tool, related to the problem being studied to produce a conclusion. Briefly, quantitative research is carried out by explaining, testing, and determining the relationship between variables by sorting the problem into parts that can be measured or expressed in the form of numbers.

RESULTS AND DISCUSSION

Results

The production scheduling referred to in this journal is the monthly production scheduling for the first year carried out in block X pit Y. This production scheduling is made to determine the coal tonnage and overburden volume that must be achieved each month in order to meet PT XYZ's production target of 500,000 tons/year taking into account the Stripping Ratio value. The results of the monthly production scheduling that has been made can be seen in Table 2.

Table 2. Production Scheduling

Bulan	***Front* Barat**		***Front* Timur**		**Produksi Batubara**	**Produksi *Overburden***	***Striping Ratio***
	Level	**Arah Kemajuan**	**Level**	**Arah Kemajuan**			
Januari	Top – RL+ 20	-	Top – RL +20	-	42,449,62	346.538,577	8,164
Februari	Top – RL+ 20	Utara	-	-	41.453,35	322.824,129	7,788
	RL+20 – RL+15	Selatan	-	-			
Maret	RL+20 – RL+15	Utara	Top –RL +25	Utara	41,032,50	327.852,49	7,990
	-	-	Top –RL +15	Selatan			
Apri	TOP – RL+05	Selatan	-	-	39.557,81	323.312,660	8,173
Mei	RL+15 – RL+05	Utara	RL +20 – RL+15	Utara	41.999,53	341.448,122	8,130
Juni	Top – RL+15	Utara	RL +25 – RL+15	Utara	39.883,00	321.568,762	8,063
	RL+15 – RL +05	Utara	-	-			
Juli	RL+15 – RL+05	Utara	Top – RL +15	Utara	43.126,19	343.614,640	7,968
Agustus	Top – RL + 05	Utara	Top – RL +15	Utara	41.034,40	322.310,234	7,855
September	Top – RL + 10	Utara	RL+20 – RL +15	Utara	43.717,71	349.937,531	8,004
Oktober	Top- - RL +30	Utara	Top – RL+15	Utara	42.590,16	341.726,626	8,016
	RL+10 – RL +05	Utara	-	-			
November	RL+30 – RL 0	Selatan	RL +15 – RL+10	Selatan	41.838,32	341.726,626	8.168
	RL +05 –	Selatan	RL+15 –	Selatan			

Bulan	***Front* Barat**		***Front* Timur**		**Produksi Batubara**	**Produksi *Overburden***	***Striping Ratio***
	Level	**Arah Kemajuan**	**Level**	**Arah Kemajuan**			
	RL0		RL0				
Desember	RL +05 – RL0	Selatan	RL+15 – RL0	Selatan	41.704,05	335.750,696	8,051
	RL0 – RL-05	Selatan	RL+10 – RL-05	Selatan			
	-	-	RL+0 – RL -05	Selatan			
Rata - Rata			500.386,685			4.018.274,2	8,030

Based on the results of the monthly production scheduling planning in the first year that has been made (Table 2), the tonnage of coal varies each month and produces a total tonnage of coal for one year of 500,386,685 tons, where the tonnage exceeds the predetermined production target of 500,000 tons/year. This is due to adjustments to the area of the mining area, bearing in mind that when making a production schedule, the area of the work front is considered.

However, the varied tonnage of coal and the excess coal tonnage with the production target has been adjusted to the capacity of the digging and hauling equipment. = Swelling Factor When viewed from economic feasibility, the production scheduling scenario that is made can be applied to mining activities because the Stripping Ratio value on a monthly basis and the Stripping Ratio as a whole still shows a value that does not exceed the Stripping Ratio value limit, which is 8.187.

Discussion

(1) Mine Progress Design

The design of the mine progress referred to in this study is the design of the mine progress in block X pit Y. This design will show how the shape of the pit from mining every month is to get coal tonnage and overburden volume in accordance with the production schedule. The design of mine progress is made by considering the geometric parameters of the slope and the geometry of the mine road. The results of the mine progress design that has been made can be seen in Figure 11 to Figure 25:

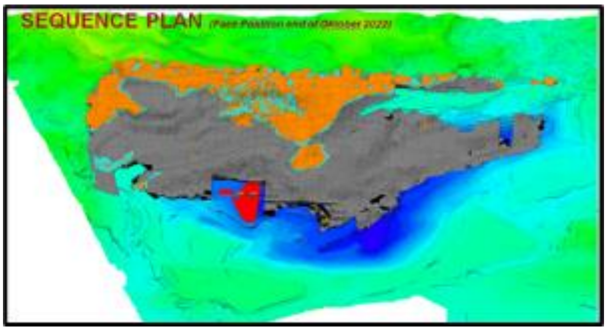

Figure 11. Mine Progress End of October 2022

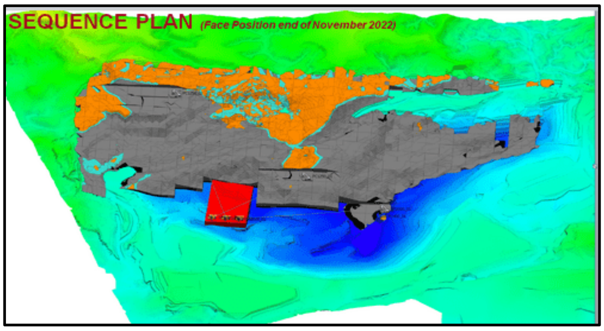

Figure 12. Mine Progress End of November 2022

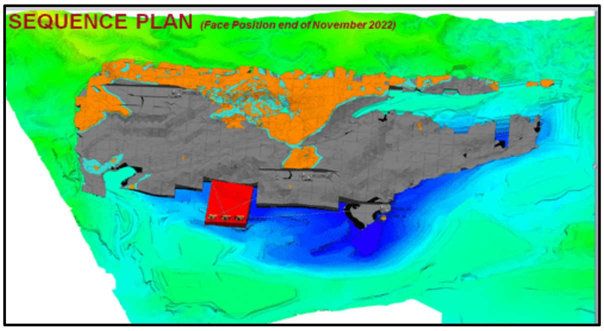

Figure 13. Mine Progress End of December 2022

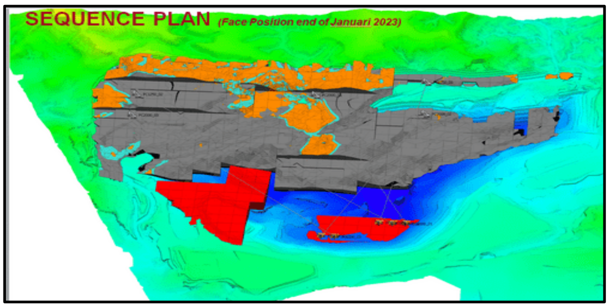

Figure 14. Mine Progress End of January 2023

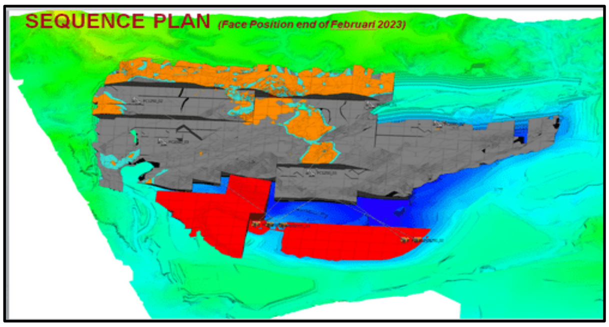

Figure 15. Mine Progress End of February 2023

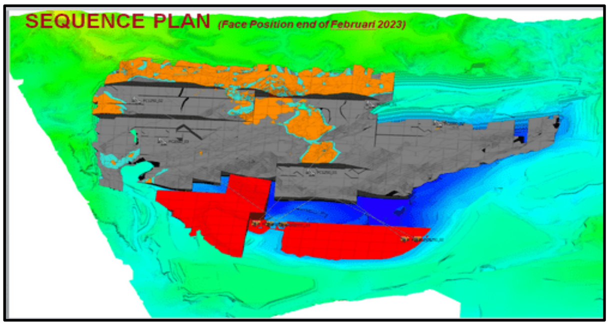

Figure 16. Mine Progress End of March 2023

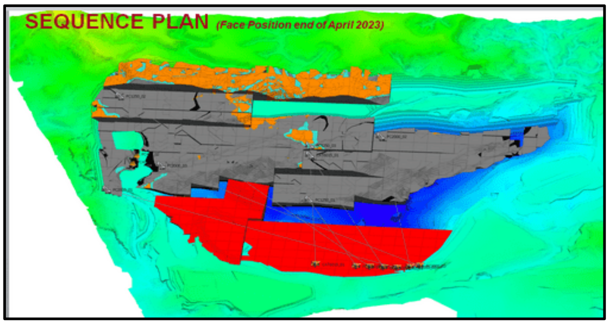

Figure 17. Mine Progress End of April 2023

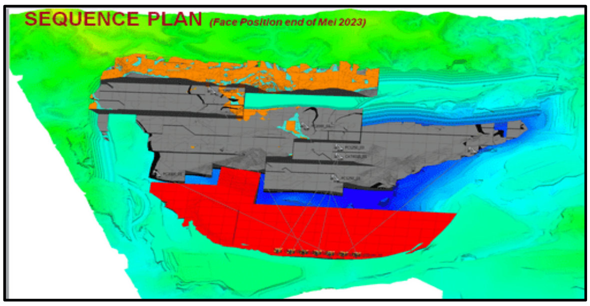

Figure 18. Mine Progress End of May 2023

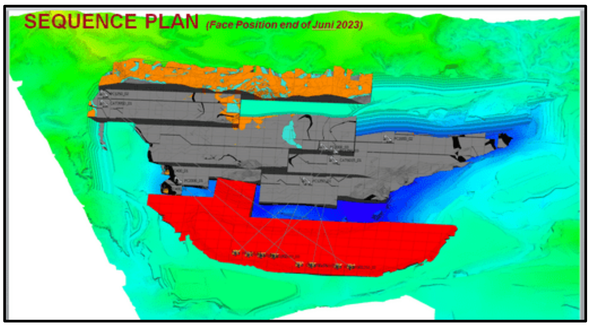

Figure 19. Mine Progress End of June 2023

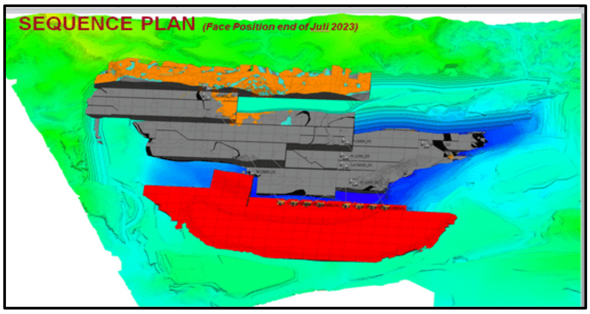

Figure 20. Mine Progress End of July 2023

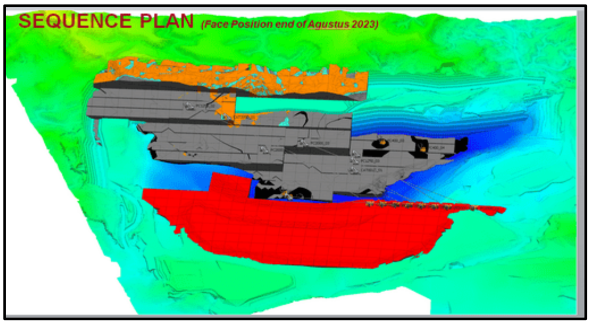

Figure 21. Mine Progress End of August 2023

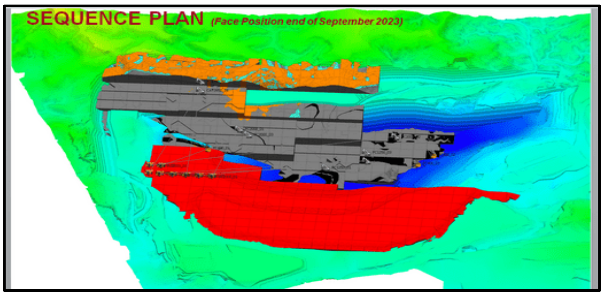

Figure 22. Mine Progress End of September 2023

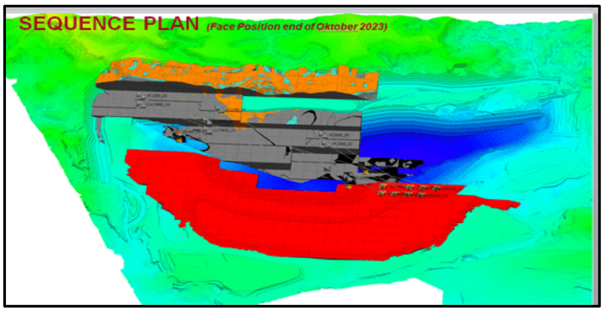

Figure 23. Mine Progress End of October 2023

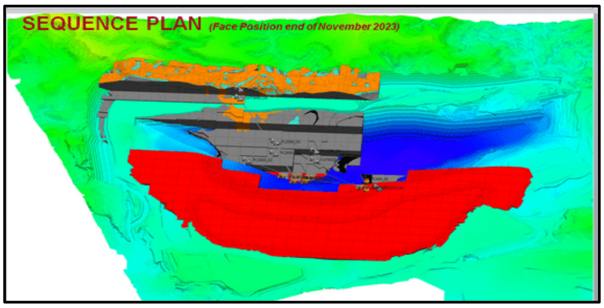

Figure 24. Mine Progress End of November 2023

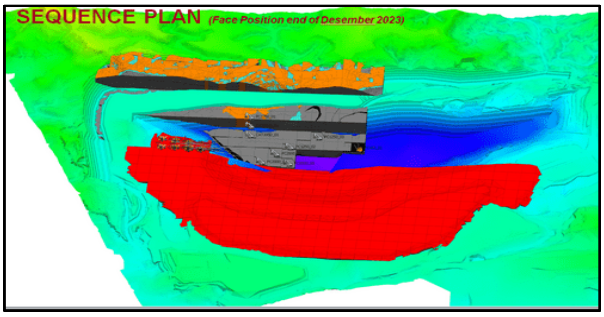

Figure 25. Mine Progress End of December 2023

Based on the mine progress plan that has been made (Figure 11 – Figure 25), in the first mining in October mining starts from overburden stripping around the outcrop after that mining of exposed coal is carried out. Then the same thing is done in the following months with a different mining direction each month. The difference in direction is due to the influence of the varying thickness of coal and overburden because in the mining progress every month you have to adjust the coal tonnage as constant as possible and you have to strip the overburden not to exceed the Stripping Ratio value.

In Figure 11-25 it can be seen that there are pictures of heavy equipment in scheduling, this is one of the advantages of the scheduling method using SPRY compared to scheduling manually. In the manual scheduling process it can usually take as long as 5 days and errors often occur because the scheduling is not yet detailed and does not take into account the heavy equipment used, but scheduling using SPRY is more effective and efficient in processing time and takes into account the capacity of the heavy equipment used.

(1) Pit Design by SPRY

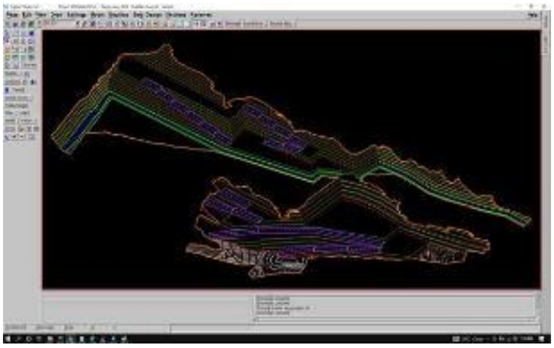

Figure 26. Pit Design by SPRY

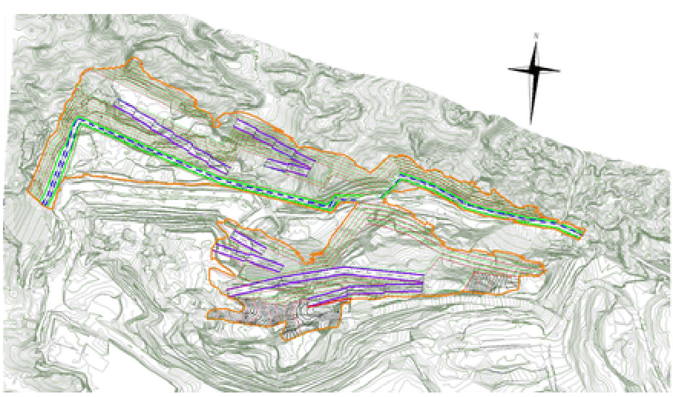

Figure 27. Pit Design by SPRY

CONCLUSION

Mine planning is paying for the technical requirements of executing firing activities and winning technical sequences for their execution to achieve objectives and activities. Meanwhile, design is part of mine planning that relates directly to geometric aspects, including mining deadlines, mining stages, and production scheduling. Meanwhile, mine scheduling is a part of the mine planning. The main goal of scheduling is to get as much profit as possible.

Mine plan/mine schedule evaluation and analysis systems are needed to make predictions of the mining operations to be carried out and can be used to find causes of deviations or design deviations. There are several weaknesses in making scheduling manually, so scheduling is done using SPRY which is very helpful in the scheduling process.

With SPRY Scheduling, the output from running at a certain time can be exported into a data grid which is then converted into a contour which will create a design from the SPRY output. So that the design has been captured in fleet capacity.

The development of the mine schedule concept is expected and recommended to be able to estimate the possibility of deviations or deviations in the design making. The results of the evaluation can be input both internally and externally to the customer to reach a meeting point in determining the ideal production target plan and target for both parties. As well as providing proposals for changes in the design and concept of scheduling which are adjusted to the approach of actual progress conditions in the working field.

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