Nguyen Quoc Long - Pham Thi Lan
Nguyen Viet Nghia - Khuong The Hung
Le Thi Thu Ha - La Phu Hien

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A STUDY ON THE DRAINAGE ABILITY OF DEO NAI, COC SAU, AND CAO SON OPEN-PIT MINES

Fomin Sergey Igorevich[1] , Do Ngoc Hoan[1*], Vu Duc Tuan[1]

1 Saint -petersburg mining university

** Corresponding author's email: Dohoan385@gmail.com*

Abstract: *Up to now, Deo Nai, Coc Sau and Cao Son openpit mines have been closely related to drainage. Especially, in near future when they carry out the exploitation in an optimal sequence to exploit all the coal in the planting areas as well as facilitate the discharging plan. This studying investigates the overall drainage capacity of three mines to meet the production requirements in the context of complicated weather conditions.*

Key words: *open-pit mines, Rainfall, basin, mining, drainage, dumping.*

1. INTRODUCTION

According to the coal development program of Vietnam, the expected coal gross output in 2020 to increase to 70 million tons per year. Based on the basis of exploiting, processing efficiently and economically using the country's coal resources, ensuring national energy security. With the orientation of turning the small-scale mines to a larger scale, exploiting sustainably and efficiently, maximizing the use of internal dumping site [1]. Accordingly, Deo Nai, Coc Sau, and Cao Son open-pit mines will be exploited in an optimal sequence to gather all the coal deposits in the border of three mines as well as mining and dumping logically. Optimizing the drainage works of the three mines in extreme weather conditions, preventing mines from flooding, landslides, destroying buildings, and contaminated environment are critical issues.

2. OVERVIEW OF THREE MINES EXPLOITING PLAN

Deo Nai, Coc Sau and Cao Son mines locate in Cam Pha city, Quang Ninh province. These are the three largest open-pit mines of Vietnam National Coal - Mineral Industries Holding Corporation Limited (VINACOMIN). In terms of location, the three mines are adjacent to each other, forming large open pit bottoms in the hilly terrain. Hot, damp weather with lots of rain have a major impact on mining. Average annual rainfall is from1700 to 2400 mm, the largest rainfall a day is from 517 to 870 mm (heavy rain from 25/7-5/8/2015, rainfall is from 500 to 870 mm). Annually, Cam Pha city is affected by an average of 5 to 6 storms, and may up to 9-10 storms. [2]

In the coming period, to thoroughly extract all resources in planting area, adjacent areas of the three mines as well as to select the appropriate way to mining and dumping for mine expansion. VINACOMIN considers all things to give an optimal exploiting process in order to optimize the sequence of exploitation, transportation, discharge and drainage for the three mines with reasonable parameters of mining system, especially in unstable weather.

Basis principles for selecting the plan of exploitation, transportation, discharge and drainage for Deo Nai, Coc Sau and Cao Son mines are as follows:

- Based on geological investigation documents, working time, and the mining rate of each mine
- Ensuring the coal gross output meets the requirement of 6 to 8 million tons per year
- Ensuring the dumping process, making use of internal dumping site and temporary dumping site. Ensuring the rock transporting road of each mine to the disposal site as well as the height does not exceed +300 level.
- Making the most use of the existing infrastructure and drainage system of the mines and in the area.
- Minimizing negative impacts on the environment.

From the basis and principle above, the most reasonable plan is these three mines coexist with the average mining rate h_s = 10-13 m/year average. Coc Sau and Deo Nai will finish exploiting by 2022 in order to make the internal dumping site and start exploiting Deo Nai - Coc Sau area [3]. According to this plan, the economic and technical indicators of three mines are shown in Table 1.

In general, these three mines are related to each other in terms of natural conditions and exploitation. To specify, Deo Nai and Coc Sau mines are connected by seam GI3a (2), there is an overlap in the removal of soil and rock as well as the general transport and dumping site between Cao Son and Deo Nai mines. Finally, they all have a mutual relation on drainage works.

3. CURRENT STATE OF DRAINAGE WORKS AT MINES

3.1 . Coc Sau Mine

- At present, the surface water drainage works at Coc Sau are carried out by the following works:

All surface water from the upper floors will be collected into the ditch system then being pumped out through drift way 1 and 2 at level +28 to drainage station before going to the sea. All water from the lower floors is collected through a drainage ditch and slope to the bottom of the pits. From here, they will be pumped with two pumping stages (from the bottom of the pit to the intermediate level -98, then from -98 to +28), escaping through the drain drift.

In general, the drainage system at Coc Sau mine still ensures the water drainage works. In particular, the pair of drain drifts at level +28 has to load a large volume of water, including a part from Deo Nai and Cao Son mines. Therefore, they are downgrade and only able to meet 75% of the drained water from heavy rains. [4]

Table 1: Summary of economic and technical indicators of mines [3]

terms	unit	Deo Nai	Coc Sau	Deo Nai – Coc Sau	Cao Son
Amount of waste removal	Mil.m^3	139,690	230,104	350,491	956,549
Raw coal	Mil.tons	13,38	20,22	34,259	95,78
Overall ratio	m^3/tons	10,44	11,38	10,23	9,99
Rock output	Mil.m^3/y	16 - 18,8	33,6 - 35	29 - 30,5	31 - 48
Coal output	Mil.t/y	1,4 - 1,8	2,7 - 2,8	2,6 - 2,7	3,2 - 4,5
height mark of pit floor	m	-225	-300	-350	-325
Mine's bottom length	m	560	250	250	1000
Ultimate pit slope	radian	29-30	29-30	29-30	34-35
Ending bench height	m	30	30	30	30
End time of exploitation	year	2015 - 2022	2015 - 2022	2023 - 2037	2015 - 2039
operating bench height	m	15	15	15	15
width of operating bench	m	40-45	40-45	40-45	40-45
width of berm	m	15-18	18	18	18
Number of layer in group	layer	3	3	3	3
Operating pit slope	radian	24-25	24-25	24-25	24-25
bank slope	radian	60-65	60-65	60-65	60-65
Shoveling jet's lenghth	m	250-300	250-300	250-300	250-300

Table 2: Drainage works of Coc Sau Mine [4]

Work's name	size, m			Water entering area	Dumping site
	lenghth	wide	height		
Ditch +60 west	1100	4	2	From level +70 west and dumping site level +135	Ditch +30 west
Ditch +80 west	1000	4	2	From ground +185 north, mining field II	Ditch +30 west
Ditch + 75 east	1500	5	2	From level +156 to level+30 east	Drain drift +28
Ditch + 100 north	1200	3	2	From level +165 to +90 north	Ditch +30 west
Ditch +30 west	800	6	3	above level +30 west	Drain drift +28
Drain drift No.1	577	2,2	1,95	Ditch level +30, water pumping from soat of open pit bottom	Drainage station
Drain drift No.2	499	2,8	2,4	Ditch level +30, water pumping from soat of open pit bottom	Drainage station

3.2 Deo Nai mine

- Surface water drainage: Gravity drainage in the Main Area from above level+35, South Lo Tri from above +160.

Main seam's drainage ways: the southern footwall of the main seam (the south of the main seam), south floor from +35 to +135, north floor from above +50 is collected through the 32K culvert and then poured into drainage drift 55 northwest and escape through drift +28. Water from the old north Lo Tri and Lo Tri's dumping site from above level +225 is collected through the ditch system leading to the Anpha ditches to the drainage station then flows into BaBe lake. At the north – west of the mine from level +225 to +55, water is leaded to drainage drift level +28.

In general, the ditch system in Deo Nai mine are similar to that in Coc Sau mine, which ensures the drainage ability of the mine at the present time.

- Forced drainage works: water from the bottom of the pit is pumped to level +45 then flows to the drainage drift level +28 by two pump system with Q = 1250 m^3/h, height = 180m +28 at Coc Sau mine. Water from the southern footwall of the main seam and south floor above level + 135 is collected through P8 culvert down to the chemical spring.

Water from south Lo Tri from above level +180 and south dumping site flows to slope 1 and 2 to the drainage station. From level -180 to +160 water flows through ditch

3.3 Cao Son coal mine

- surface water drainage

+ Water at the western area of the mining field from level +30 to +120 and north site of the mine enters the ditches located at the foot of the mining layer then flows to Da Mai stream.

+ Water at the South and South East site of the mine next to Dong Cao Son dumping site flows through drainage ditches + 70 to + 80 then escapes by drift +28 of Coc Sau mine.

+ Water at Dong Cao Son dumping site adjacent to Vu Mon Stream escapes through the dirt stopping dam No. 3 into Vu Mon Stream.

+ Bang Nau dumping site drains into drain pit then flows into Bang Nau stream or Diem Vong river.

- Mining filed drainage: All water from the bottom of the mine is drained by 5 pumping to the transshipment at -75 is then pushed to +97, and finally be discharged at level +75 at the north of the mining field and then gathered at the equalizing lake of drainage station. The 1,163m drain line is a total disadvantage.

In general, all existing works ensure the drainage of the surface water . according to the test results

Drainage also has a great influence on one another. For example, the water of Cau Sau and Deo Nai and apart of Cao Son mine drains through the system of trenches of Coc Sau and flows to the drift+28, then flow to the drainage station and discharges to the sea. Therefore, without an overall control, there will be obstacles, compromises and even disputes.

4. STUDY THE OVERALL DRAINAGE CAPACITY OF THE THREE MINES

4.1 Drainage of surface water

The strategic plan to develop the common drainage system for the three mines is built on the following basic principles: minimizing surface water flowing down the open pit bottom, making most used of the existing drainage works and draining must go along with the regional exploiting and dumping plan.

To investigate surface water drainage for these mines, we conducted a survey on the amount of the overflow rainfll over the valleys during the largest rain. To calculate the amount of the over flow run off in the basins we use the following expression [5]:

$$Q = q \cdot F \cdot \psi, m^3 \quad (1)$$

In which: q – Rainfall of the biggest rain, m; Ψ - surface water flow factor, Ψ = 0.5 - 1.3

Through surveying and calculating 11 basins of Deo Nai mine, 12 basins of Cao Son mine and 8 of Coc Sau mine, we have the result of the inflow of water into mines as shown in the diagrams in Figure 1, 2 and 3.

From these above calculations, we balance the drainage capacity of the works shown in Table 3:

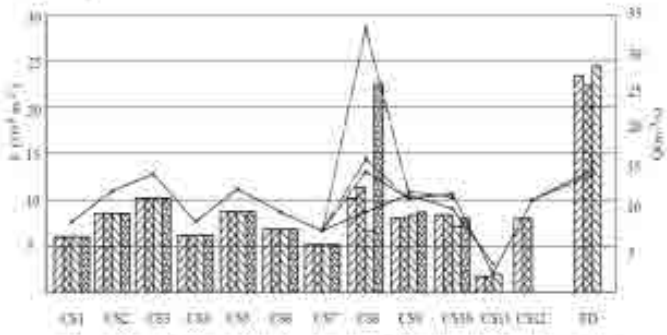

Figure 1: Rainfall on each basin of the Cao Son coal mine

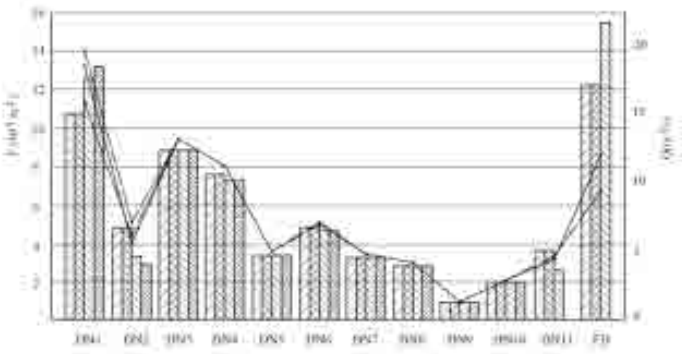

Figure 2: Rainfall on each basin of the Deo Nai coal mine

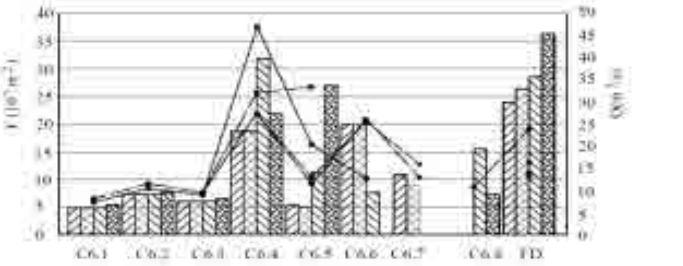

Figure 3: Rainfall on each basin of the Coc Sau coal mine

Area to receive rain of mines: 2017 ☒ 2018 ☒ 2022 ☒ end ☒; Rainfall on each area of mines: 2017 —— 2018 —·— 2022 - - - - end —··—; CS1, CS2,…, DN1, DN2,…, C6.1, C6.2,…: basins to receive rain of mines; FD: Forced drainage.

4.2 Forced drainage

To calculate mine's forced drainage, we base on the largest amount of water flowing into the bottom of the mine in the year, the quantity and the working parameter of the pump as well as the status of current drainage works of mine. The drainage calculation must ensure that the mine can drains water until mine finishes exploiting.

The amount of water needs pumping in one hour and drainage height requirement are in turn determined by these expressions [5]:

$$Q_{cb} = \frac{Q_M}{\theta \cdot N \cdot T}, m^3/h \quad (2)$$

$$H_{yc} = \frac{H_{hh}}{\eta}, m \quad (3)$$

In which: Q_M – the amount of water flows down the pits during the three rainy months, m^3; N – Draining day, days; θ - Productivity of the pump, θ = 0.8-0.9; T – working time of the pump in one day and night, T = 20h; H_{hh} - geometric drainage height, m; η - Coefficient of network utilization.

According to mine survey calculations by years of exploitation, the largest flow of water into mines (Figure 1, 2 and 3) is as follows:

Deo Nai mine has the largest waterfall flows to the bottom of the pits reaching 11.86 m^3/s in 2022 (end of exploitation) when the mine reaches cos -225, the geometric height of the pumping rod is 265m.

Cao Son mine has the largest water fall flows into the bottom of the pits reaching 23.58 m^3/s in 2039 (end of exploitation) when the mine reaches cos -325, the geometric height of the pumping chamber is 375m in the south. The

north area of the mine will be finished by 2022, the geometric height of the pumping rod is 180m.

- Coc Sau will exploit to 2022 at level-300, a waterfall flows to the bottom of the pits reaching 16.42 m^3/s, the geometric height of the pumping rod is is -328m.

- When exploiting the coal between Deo Nai and Cau Sau, the largest rainfall flows to the bottom of the pits reaching 23.58 m3/s by 2037 (end of exploitation) at the level of -350 m escaping to drain +80. The geometry height of the pump is 430m.

Table 3: Balacing drainage capacity of mine's building.

Terms	Origin	Largest water fall, $Q_{max}(m^3/s)$			
		2017	2018	2022	end
Drainage needs through drift +28	ĐN2, ĐN11; CS11; C6.5; C6.6.	51.17	51.17	42.86	40.36
Drainage capacity of drift +28		36.27			
balancing		**-14.9**	**-14.9**	**-6.59**	**-4.09**
Drainage needs through Cau 2 spring	ĐN3, ĐN4; C6.7.	34.95	34.95	23.61	23.61
Drainage capacity of Cau 2 spring		57.6			
balancing		22.65	22.65	33.99	33.99
Drainage needs through Cau 3 spring	ĐN5.	4.88	4.88	4.88	4.88
Drainage capacity through Cau 3 spring		28.56			
balacing		23.68	23.68	23.68	23.68
Drainage needs through Cau 4 spring	ĐN6; ĐN7.	11.7	11.7	11.58	11.58
Drainage capacity of Cau 4 spring		28.56			
balancing		16.86	16.86	16.98	16.98
Drainage needs through Cau 5 spring	Drift+28; ĐN1; ĐN8; ĐN9; ĐN10.	75.56	75.56	69.36	67.88
Drainage capacity of Cau 5 spring		392			
balancing		316.44	316.44	322.64	324.12
Drainage needs through Khe Re spring	C6.4; C6.8.	27.28	27.28	46.70	42.70
Drainage capacity of Khe Re spring		50.40			
balancing		23.12	23.12	3.70	7.61
Drainage needs through 790 spring	CS4; C6.3.	17.94	17.94	17.94	18.55
Drainage capacity of 790 spring		48			
balancing		30.06	30.06	30.06	29.45
Drainage needs through H10 spring	CS3;C6.2.	25.38	25.38	25.38	26.28
Drainage capacity of H10 spring		45			
balancing		19.62	19.62	19.62	18.72
Drainage needs through +9,8 spring	CS2; C6.1.	19.7	19.7	19.7	20.63
Drainage capacity of +9,8 spring		24			
balancing		4.3	4.3	4.3	3.37
Drainage needs through Vu Mon spring	CS10.	12.32	12.32	10.51	11.79
Drainage capacity of Vu Mon spring		30			
balancing		17.68	17.68	19.49	18.21
Drainage needs through Da Mai spring	CS5; CS8, CS9; CS12.	51.26	53.01	35.17	58.77
Drainage capacity of Da Mai spring		100.8			
balancing		49.54	47.79	65.63	42.03
Drainage needs through Bag Nau spring	CS1; CS6; CS7.	26.49	26.49	26.49	29.49
Drainage capacity of Bang Nau spring		134.4			
balancing		107.91	107.91	107.91	107.91

Table 4: The amount of water flows down the pits during and geometric drainage height

Mines	Pump station	$Q_M (m^3)$				H_{hh} (m)			
		2017	2018	2022	end	2017	2018	2022	end
Deo Nai	No.1	4899894	5403712	6263073		120	135	115	
	no.2	4899894	5403712	6263073		88	90	75	
	no.3			6263073				75	
Coc Sau	no.1	6807231	7444105	8149059		139.5	70	115	
	no.2	6807231	7444105	8149059		128.6	87	87	
	no.3		7444105	8149059			128.6	128.6	
Cao Son	no.1	4113417	4236858	5379338	12685511	50	75	110	150
	no.2	4113417	4236858	5379338	12685511	170	170	170	150
	no.3	4079096	4173571	3817480		140	140	120	
	no.4			3817480				60	
Deo Nai –	no.1				8788135				125

Coc Sau	no.2				8788135				120
	no.3				8788135				120
	no.4				8788135				65

Table 5: flow and pressure requirements of pump station

Mines	Pump station	Q_{cb} (m^3/h)				H_{yc} (m)			
		2017	2018	2022	end	2017	2018	2022	end
Deo Nai	No.1	2772.2	3002.1	3479.5		150	168.8	143.8	
	no.2	2772.2	3002.1	3479.5		110	112.5	93.8	
	no.3			3479.5				93.8	
Coc Sau	no.1	3781.8	4135.6	4527.3		174.4	87.5	143.8	
	no.2	3781.8	4135.6	4527.3		160.8	108.8	108.8	
	no.3		4135.6	4527.3			160.8	160.8	
Cao Son	no.1	2285.2	2353.8	2988.5	7047.5	62.5	93.8	137.5	187.5
	no.2	2285.2	2353.8	2988.5	7047.5	212.5	212.5	212.5	187.5
	no.3	2266.2	2318.7	2120.8		175	175	150	
	no.4			2120.8				75	
Deo Nai – Coc Sau	no.1				4882.3				156.3
	no.2				4882.3				150
	no.3				4882.3				150
	no.4				4882.3				81.3

Table 6: Position of the pumps

Mines	**Pump station**	**level**	**2017**		**2018**	
			Pump status	quantity	Pump status	quantity
Deo Nai	T.1	-30	1250 m^3/s;180 m H_2O	3+1	1250 m^3/s;180 m H_2O	3+1
	T.2	-150	1250 m^3/s;100 m H_2O	3+1	1250 m^3/s;100 m H_2O	3+1
	T.3	-220				
Coc Sau	T.1	-98	1250 m^3/s;180 m H_2O	3+1	1250 m^3/s;180 m H_2O	4+1
	T.2	-185	1040 m^3/s;198 m H_2O	3	1250 m^3/s;180 m H_2O	2+1
			1026 m^3/s;180 m H_2O	1+1	1400 m^3/s;129 m H_2O	2
	T.3	-300			1250 m^3/s;180 m H_2O	1
					1040 m^3/s;198 m H_2O	2+1
					1026 m^3/s;180 m H_2O	1+1
Cao Son	T.1	-100	1080 m^3/s;180 m H_2O	2+1	1080 m^3/s;180 m H_2O	2+1
	T.2	-250	1250 m^3/s;220 m H_2O	2+1	1250 m^3/s;220 m H_2O	2+1
	T.3	-325				
	T.4	+20	1250 m^3/s;180 m H_2O	2+1	1250 m^3/s;180 m H_2O	2+1
	T.5	-100				

Mines	**Pump station**	**level**	**2022**		**end**	
			Pump status	quantity	Pump status	quantity
Deo Nai	T.1	-30	1250 m^3/s;180 m H_2O	3+1		
	T.2	-150	1250 m^3/s;100 m H_2O	3+1		
	T.3	-220	1250 m^3/s;100 m H_2O	3+1		
Coc Sau	T.1	-98	1250 m^3/s;180 m H_2O	4+1		
	T.2	-185	1250 m^3/s;180 m H_2O	2+1		
			1250 m^3/s;180 m H_2O	2		
	T.3	-300	1250 m^3/s;180 m H_2O	1		
			1040 m^3/s;198 m H_2O	2+1		
			1026 m^3/s;180 m H_2O	1+1		
Cao Son	T.1	-100	1080 m^3/s;180 m H_2O	3+1	1250 m^3/s;180 m H_2O	6+1
	T.2	-250	1250 m^3/s;220 m H_2O	3+1	1250 m^3/s;220 m H_2O	6+1
	T.3	-325			1250 m^3/s;180 m H_2O	6+1
	T.4	+20	1250 m^3/s;180 m H_2O	2+1		
	T.5	-100	1250 m^3/s;180 m H_2O	2+1		
Deo Nai – Coc sau	T.1	+15			1250 m^3/s;180 m H_2O	4+1
	T.2	-105			1250 m^3/s;180 m H_2O	1
					1040 m^3/s;198 m H_2O	3
					1026 m^3/s;180 m H_2O	1+1
	T.3	-225			1250 m^3/s;180 m H_2O	4+1
	T.4	-350			1250 m^3/s;100 m H_2O	4+1

Noted: (3+1) stands for 3 working pumps and 1 for backup.

At present, mines' pumps have the pumping height of 100 mH2O to 220 mH2O and a flow rate of 1000-1250 m3/h. Based on existing pumping equipment and drainage works the authors propose to calculate the layout of the pumping stations with the flow and the required pressure of the pump is determined by the years of operation shown in Tables 4, 5 and 6.

5. CONCLUSIONS

- Quang Ninh has very complicated weather conditions, especially in rainy season. This has caused a great deal of economic damage as well as production delaying in mining.

- Researching and calculating the reasonable drainage capacity for Deo Nai, Coc Sau and Cao Son mines in the coming time is very necessary. Because these mines have a mutual impact on each other about exploitation, drainage and disposal of soil and rock.

- This study has been calculated drainage planning of three mines in both surface water drainage and forced drainage. Calculations are calculated until the completion of mine operations on the basis of making the most use of the existing drainage works and facilities available at the mines.

ACKNOWLEDGMENT

This paper studies the general drainage capacity of Deo Nai, Cao Son, and Coc Sau mines (Vietnam). The author has calculated the surface and underground water drainage of three mines from now til the end of mining.

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