Open Pit-Mine Water Management in Equatorial Area

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Abstract

PT Kaltim Prima Coal, currently the largest open-pit coal mining company in Indonesia, is located in East Kalimantan. A province passed by the equator experiences heavy rainfall throughout the year. Annual average rainfall is recorded at 2,152 mm. Controlling water inflow quantity is the most important thing in water management to have decent water quality. Proper design configuration consists of dry dam as flow detention and labyrinth pond for quality adjustment. Water discharge reduction up to 90% in average brings enormous benefit for water management system. Also, the design becomes the most feasible option in post mining.

Keywords: Rainfall, Water Management, Mining, Equator

Introduction

PT Kaltim Prima Coal (KPC) is one of the largest coal mining companies in Indonesia. It is located in the province of East Kalimantan. Geographically, the region is crossed by the equator which leads to weather conditions. In general, Indonesia consists of two seasons, dry and rainy seasons. Rain occurs throughout the year without meaningful seasonal differences.

From 1998 to 2012 the sediment ponds configuration used at KPC was categorized in 2 types. First was a blocking sediment pond with large dead reservoirs on hilly areas and the second was labyrinth type sediment pond which was built in area that tended to be flat and there were no insulated hills. This typical labyrinth pond had a small storage capacity and expensive cost. Looking further into other ponds in other mines, configurations were also commonly used in other coal mines in Indonesia.

Sediment ponds in KPC generally manage catchment in the average range of 1 km^2 to 6 km^2. Combination of a large enough catchment and high rainfall will generate a large water discharge outflow. Such condition causes difficulty on water considering the runoff discharge when it rains is enormous and uncontrolled. Refer to Indonesia regulation of energy and mineral resources ministry 7/2014 concerning the implementation of land reclamation of former settling ponds as part of post-mining. So it can be defined that in the post mining stage sediment pond must be able to be changed into a wetland and does not leave the risk of dam break and or failure in the future. According to status of notifiable and other dams at KPC 2008 report study (Simmons 2008) conducted at KPC, in the construction of dam blocking, the accumulation of sediment that occurred in the ponds increased hazard structure such as overtopping, internal erosion (piping), slope stability, and foundation failure in the long term operation.

Answering the problems, KPC has revolutionized the sediment pond configuration. Starting from the design concept which was developed in 2013 and made changes and improvements to date. The total sediment pond that has been built using this new configuration method is 11 ponds, where the total number sediment ponds that have successfully been transformed into the new configuration are 4 ponds. Configurations includes building 2 types of settling ponds in each KPC managed catchment area which has huge live storage pond system as shown in the scheme in Figure 1 below. Two types of ponds built were (1) the type of dam blocking with a dry dam concept and (2) labyrinth pond. Dry dam ponds function to regulate the outflow and labyrinth ponds function

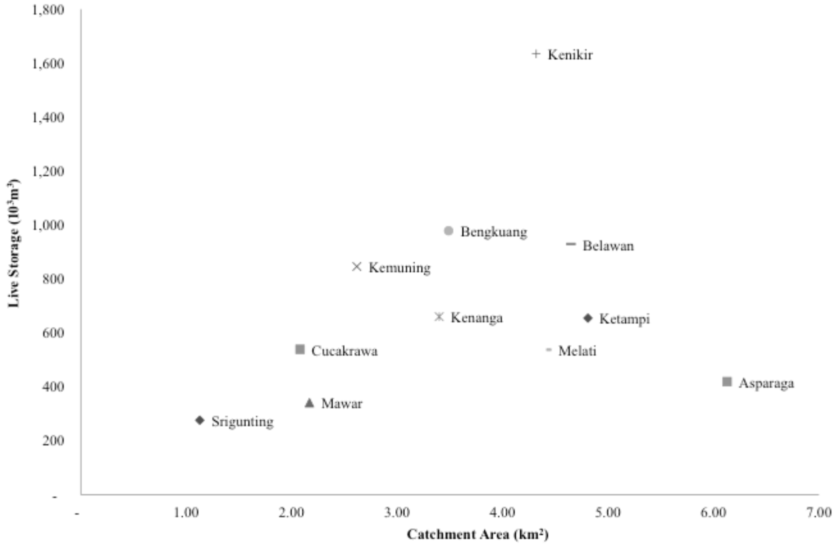

***Figure 1** Registered sediment pond using new configuration system in KPC area.*

as settling ponds. A model example of this detention dam on KPC operation is shown in this paper. Basic principles and methods of such a solution are shown.

Methods

Currently 18 rain stations are actively operated in KPC, with a wide coverage area throughout the mining area of PT KPC. Analysis of the average regional rainfall implemented to calculate the weighing of each rain station uses the polygon Thiessen method. Data consistency test is also carried out to find whether there are environmental changes and or changes in how to measure rain data. If the test results state that the rainfall data is consistent it means that there are no changes to these 2 variables (Haan et. al. 1994). Results of the data processing are then presented in the form of rain design with a certain return period. Where the return period is defined as a hypothetical time where rain or discharge with a certain amount will be equaled or exceeded once in that time period.

Hydrograph is a graphic presentation of one of the flow quantities as a function of time (Chow 1988). Hydrograph shows the overall response of the catchment area to rain inputs. Unit hydrograph is a direct runoff hydrograph produced by effective rainfall evenly distributed in a catchment area with a fixed intensity (taken 1 mm/hour) in a set unit of time (taken 1 hour). For rivers that do not have observable flood hydrographs, synthetic hydrographs that have been developed in other countries are usually used, the parameters of which must be adjusted first to the characteristics of the drainage area under review.

Therefore, building a dry detention reservoir is a very progressive solution nowadays. It is an effective water structure, which has no noisy effects on the environment and can even be an aesthetic part of the countryside. It has to retain the flood wave and prevent an odd amount of water from flowing outside the river bed. Minimizing flood risk can be achieved in three ways (Cipovova 2011):

- Decreasing the accumulated discharge. This can be provided by water structures, weir dams, detention reservoirs or flooding less valuable parts of a region
- Increasing the capacity of a water course
- Instituting corrections and arrangements in the flooded area (e.g. planning, warning, and rescue services).

Rain that occurs throughout the year in the KPC active operational area requires proper methods of management. Analytical methods used in calculating and designing a structuring point pool include and are not limited to:

- Preliminary Design shall be part of general water management plan based on official version of 5 Years Long Term Water Management Plan.
- Development conceptual design which includes sediment pond control location. Location must be considered to its safe distance from public facilities and main water course. Also in addition for practical reason must refer to ministry decision of energy and mineral resources 1827-2018. Conceptual design shall also follows criteria below:
    - *Pond Configuration*
      Pond configuration consists of two types, control discharge fill embankment and excavated labyrinth pond as settling pond. Discharge inflow run off from catchment area is controlled and the discharge is reduced by using filled embankment. Within low discharge from outflow point of filled embankment, water quality could be settled easily at labyrinth pond.
    - *Type of outlet and emergency spillway*
      Typical of outlet on the embankment and excavated pond is defined by two. Low level intake as main water flow and emergency spillway to cover unplanned rainfall or discharge happen in the future.
    - *Storage capacity and structure examination*
      The examination is including water storage capacity both of dead storage and live storage (temporary). Also the examination of the embankment height refers to Indonesia minister regulations of public works and public housing ministry 27/PRT/2015.
    - *Geotechnical investigation and assessment*
- Development of detail design which includes catchment, rainfall, runoff, all of hydrologic and hydraulic aspect, sedimentation rate, and also maintenance schedule.

Result

Rain data is obtained from rain stations that are scattered in all catchment areas of the pond and there is also an automatic rain station which is useful for getting rainfall events data. Rain data from manual monitoring has been collected since 1985. Based on a study of automatic rain data, the concentration of rain events is 3 hours. The percentage distribution of rainfall events is 22.6% at the first hour, 63.5% at the second hour and 13.5% at the third hour. The average annual rainfall is 2,152 mm, 179 mm monthly and 5.7 mm daily.

For sediment ponds, there are two classifications of storage which are divided into two reservoir levels. Live storage is the reservoir volume that is above the low level intake elevation to the crest dam elevation and functioned as a discharge detention. Dead reservoirs as sediment reservoirs volumes are below the elevation of the low level intake to the bottom of the ground level of water storage. In the use of ponds as discharge detention, volume of live storage must be optimized.

Detention pond construction is carried out by placing an outlet at the bottom of the sediment pond, sedimentation is planned to occur in the labyrinth pond. Sediment pond embankment is maximized to control water discharge. To maximize its function, it is done by installing the outlet capacity in lowest level available and considering the availability of storage that can be provided. In this scheme, the outlet must use a closed channel type such as pipe or concrete box culvert.

Flood event is simulated within 24 hours. Calculation is done by Nakayasu synthesis unit hydrograph. Parameters involved in the synthetic hydrograph analysis using Nakayasu HSS are (1) time to peak magnitude, (2) time lag, (3) time base of hydrograph, (4) catchment area, (5) length of the longest channel, and (6) run off coefficient (Soemarto 1986). If it depictes in the hydrograph scheme, the peak of the flood occurs within the first 3 hours. High incidence of rain and concentrated in a short time raises the potential for flooding if no control of water discharge arises. One option that can use discharge control

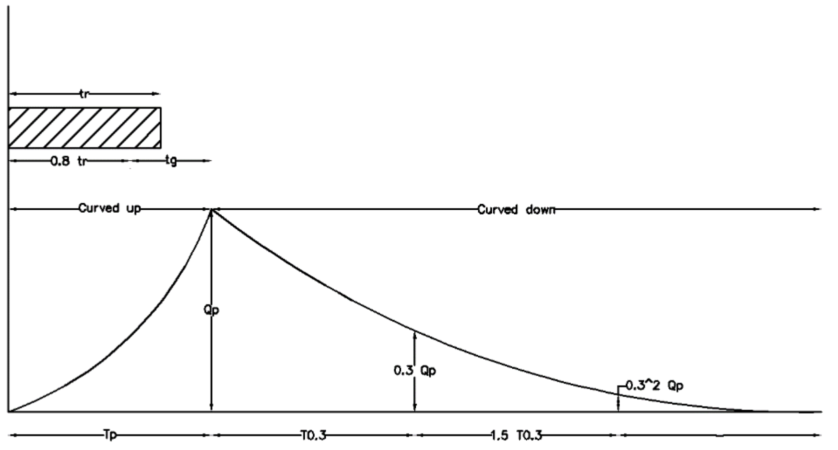

***Figure 2** Hydrograph synthetic scheme of HSS Nakayasu.*

using the detention dam principle. Figure 2 describes the main forming of hydrograph scheme in certain condition.

In the detention pond, discharge reduction that comes out compared to incoming discharge can reach up to 90% in average. In some sediment ponds that have applied the detention pond concept the following discharge decreases are obtained in the table 1. Column (e) describes percentage of total discharge reduction happens in the system. Averagely, the discharge reduction could be optimized above 90% from total peak inflow discharge. Commonly, the low level intake placed as main intake is using HDPE pipe 355 mm with the number of installation line adjusted to meet operational capacities.

Small capacity of the outlet compared to the incoming water discharge makes the water temporarily accommodated in the pond's live storage which will later come out slowly until it returns empty when there are no additional rain events. In this connection the height of the water level in the pond will

***Table 1** Discharge reduction calculation resume.*

Sediment Pond	Peak Inflow Discharge (m^3/s)	Peak Outflow Discharge (m^3/s)	Live storage (m^3)	Discharge Reduction (%)	Low level intake types
(a)	(b)	(c)	(d)	(e)	(f)
Cucakrawa	15.35	6.09	538424.00	60.33%	300mm steel pipe riser
Mawar	14.77	1.05	340341.00	92.87%	3x355mm HDPE pipe
Kemuning	18.42	1.92	845560.00	89.56%	1000mm concrete box culvert
Kenanga	37.33	2.26	659620.84	93.95%	4x355mm HDPE pipe
Kenikir	43.43	1.05	1634000.00	97.59%	3x355mm HDPE pipe
Kecubung	48.18	1.34	2420402.00	97.22%	3x355mm HDPE pipe
Melati	52.28	0.81	537027.00	98.46%	4x355mm HDPE pipe
Ketampi	37.11	0.80	653999.19	97.84%	1x1000 steel pipe
Asparaga	8.31	2.53	418304.00	69.55%	1x355mm HDPE pipe and 1x1000mm steel pipe
Kelayang	91.33	5.20	961019.83	94.31%	3x355mm HDPE pipe

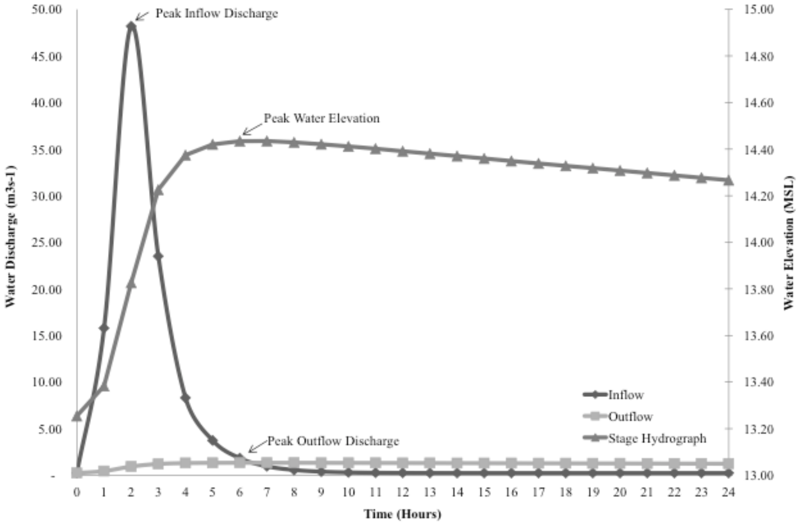

Figure 3 *Discharge routing graph scheme in general.*

rise rapidly and will go down in the span of time according to the capacity of the outlet. Result of such calculation is shown in the table 1 and general scheme applied in the calculation can be found in figure 3.

Topographical conditions greatly affect the possibility of the volume of live storage that can be obtained. It is necessary to choose the right outlet capacity with the volume of storage that can be provided. Calculation of compatibility between outlet capacity and storage capacity is calculated with the water balance between the volume of water entering, the capacity of the outlet and the storage volume. The condition to be achieved is the reduction of outflow compared to the incoming water discharge, it is expected to reach less than 10% of the value of inlet flow and the water can still be accommodated in the detention pond. Determination of the percentage of discharge detention is carried out in this process, the availability of live storage volume is proportional to the percentage of discharge reduction that can be applied.

In the next compartment (labyrinth pond) is a place where sedimentation of dissolved and suspended particle in runoff water is expected. Sedimentation is the process of separating solids from liquids (slurry) by utilizing gravity deposition. Application of this concept has succeeded in reducing the cost of water quality treatment for each cubic meter. Discharge coming out of the detention pond directly decreases the horizontal flow rate in the labyrinth pond. When compared to the absence of discharge control, the ratio of vertical velocity (particle deposition velocity) will be greater than the horizontal velocity (flow velocity) if there is a discharge control pool thereby increasing the potential for settling in the labyrinth pond. With an increase in the natural deposition process, it decreases the need for coagulants to separate dissolved or suspended material in the stream.

If using a larger outlet capacity, it will result in a higher flow velocity or horizontal speed, which will affect the effectiveness of the deposition process. Trash rack is needed to prevent the outlet from clogging. Periodic cleaning must be done on the trash rack. Trash rack is installed in front of the pipe outlet to prevent the entry of trash or other barrier material that can be carried by runoff water.

There are deficiencies in the application of detention ponds, deposition of discrete particles in the upstream part is inevitable. The length of time left makes the flow velocity slowed down so that the process of settling discrete particles will occur naturally. However, when a high flow of discharge occurs, the precipitate will be able to be swallowed by the flow into the next compartment. In addition to facilitating water quality processing operations, detention ponds directly protect the lives of civil society in the downstream part of the pond by preventing flooding.

Dry dams are much more advantageous than usual impounding dams in the point that sediment is not trapped as much as possible. Detention ponds that do not store sediment will facilitate the decommissioning process of the pond at the end of the mining period. After mining activities are completed, sediment dredging is not necessary, because all sediment entering the pond is channeled downstream for sedimentation and dredging is carried out periodically in the labyrinth pond.

Based on the regulations in force in Indonesia set by the environmental agency, when decommissioning, the company must be able to ensure that the quality of water that will come out of the sediment pond must meet quality standards for a long time even without processing activities. When compared to the weir pond that holds sediment, at the end of the mine there is an accumulation of sediment that must be cleaned before the pond can be decommissioned.

Conclusions

Application of such method has successfully deducted peak of water inflow discharge up to 90% in average from its peak. Low discharges are aimed to diminish cross sectional area of labyrinth since it is linear. Meanwhile, sedimentation process is designed to be occurred on labyrinth.

These schemes successfully bring several advantages for water management system in KPC. Firstly, operation of water treatment facility becomes more effective and more efficient since water flow discharge has been conditioned to be relatively low and constant. Secondly, sediment pond maintenance becomes easier to be managed as several options emerge to recover pond capacity. Also, it becomes the most feasible option in closing the operation in post mining stage; hence, environmental regulatory risk could be eliminated.

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