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Research Article

Mine Water Management – A study at Edikan Gold Mine (EGM)

Raymond Ninnang Tiile * , Darfour Nicholas **

Abstract
Water is an essential part of all mining activities and the availability of quality water year round is critical to mining operations. Mine water is largely employed in drilling, dust suppression, mineral processing and other in-pit operations. Shortage of water in a mine results in poor drilling control, dust pollution, and mill shutdowns, hence a critical need to optimize the use of water in various mining processes. This paper seeks to establish an effective mine water management system at Edikan Gold Mine (EGM) to have enough water in store for drought conditions. A site water balance was established primarily taking into accounts the inflows and outflows of water at the mine. Results show that rainfall and the Asuafa River are the principal sources of water for EGM mining operations, while the processing plant was the main water user on the mine site. Annual net water balance is also estimated to help determine the required capacities of future water storage facilities.

Keywords
Mining–water balance–water management–inflows–outflows

* Department of Mining, Missouri University of Science and Technology, USA Email: rntzq7@mst.ed
**Rocksure Limited, Ghana Email: darfournicholas@yahoo.com

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1. Introduction

Water plays a key role in mining processes including drilling operations, dust suppression, mineral processing and other in-pit operations. Shortage of water at the mine results in poor control over drilling activities, dust pollution, possible mill shut down, and other undesirable outcomes. On the other hand, excess mine water without appropriate storage and/or control could result in the discharge of polluted water into nearby streams with downstream consequences. Therefore, an effective mine water management system is of paramount importance. An effective mine water management system can be designed by evaluating water inflows, water use and water outflows.

This paper seeks to identify the main water users at Edikan Gold Mine (EGM) and to evaluate water needs to ensure adequate supply of water during future drought conditions. The annual net water balance is calculated based on the total water input and output and used to help determine capacities of water storage facilities.

2. Materials and Method

2.1 Relevant information about mine

2.1.1 Location and accessibility

Edikan Gold Mine (EGM) is located in Ghana, West Africa, approximately 57 km to the SW of Obuasi and 195 km WNW of the capital Accra. The Mine is located in the Central Region of Ghana, on the eastern flank of the highly productive Ashanti Gold Belt. It is located 16 km west of Dunkwa, near Ayanfuri in the Central Region of Ghana. EGM lies between latitude 1°50'00" and 2°00'00" and longitude 5°48'49" and 6°00'00". The mine can be accessed by a 107 km road from Kumasi, which lies to the north of the mine and a 186 km road from the port of Takoradi at the south of the mine. The defunct Dunkwa/Awaso railway line passes 2 km north east of the mine. The national capital, Accra is located 195 km to the ESE of the mine and a distance of 320 km by road via Obuasi.

2.1.2 Climate

The project area has a south-western equatorial climate with seasons influenced by the moist south-west monsoon winds from the South Atlantic Ocean and the dry north-east trade winds. The mean annual rainfall is approximately 1500mm with peaks of more than 170mm per month in June and October. November through February are the drier months with 20 to 90mm per month of rainfall. The mean annual temperature is approximately 25°C with small daily temperature variations. Relative humidity varies from 61% in January to a maximum of 80% in August and September.

2.1.3 Mine operations

Africa Mining Services (AMS) is being contracted to operate the mine. The gold mine currently uses an open pit mining method to extract ore in two main pits. Mining progresses using bulk waste stripping on 5m and 10m benches. Full capacity commercial production began in 2011 and the mine has over 10 years of mine life. The mining operation begins with drilling of holes, loading the holes with explosives and blasting. After the rocks have been broken up by blasting, they are loaded into haul trucks using excavators. Ore is hauled to the ore stockpile or direct-tipped into the crusher, waste rock is taken to the waste dump. As mining progresses, it is necessary to dewater the mine to ensure that the water level remains below the pit floor. Thousands of gallons of water are pumped from the pit each day. Much of the water is reused on site to control dust. Surplus water is treated and discharged back into nearby rivers.

2.1.4 Ore Processing

A 5.5-Mtpa carbon-in-leach (CIL) plant composed of primary gyratory crushers is used in the mineral processing. Once the ore is mined, it is fed to crushers and grinding mills to reduce the size of the ore and expose the gold. Water is added in the process to form a slurry. This slurry is then passed on to leaching tanks where cyanide solution is added to leach the gold into the solution. Carbon granules are put into solution for gold attachment. Gold is then stripped from the carbon granules using caustic cyanide solution and the gold bearing solution is pumped through electro-winning cells to concentrate the gold. The gold is smelted on site to form bullion bars which contain about 60 to 95% gold. The gold bars are send to a refinery for further processing into pure gold.

2.2 Mine water management

Water management involves the planning, developing, distributing and managing water resources. Water management planning examines all competing demands for water and seeks to apportion water to satisfy all uses and demands [1]. Proper management of mine water can be achieved only after mining companies manage water as an asset across environmental, social, and economic dimensions [2].

A comprehensive site Water Management Plan (WMP) is vital to sustainable water management. It should include a quantitative evaluation of water supply and use and the potentially adverse impacts of operations on local and regional water resources. The WMP identifies all water management issues associated with developing, operating and decommissioning a project [1]. A proper site water management must include water consumption measurement systems which quantify the amount of water used in each step of the mining production process. Additionally, a detailed water balance must be created that assesses the current water balance, provides corrective actions that reduce consumption, assesses the impact of water management actions and considers water management practices in future mine planning.

2.3 Water balance

Water balance is a process used to determine the quantity of water in storage and/or moving between tasks or storages, in order to support decision making and/or reporting [1]. Water balance signifies the relationship between input and output of water across a defined system boundary, such as the mine boundary or concentrator. If input is greater than output, storage within the system increases; if input is less than output, storage decreases. In simple mathematical form:

Change in Storage = Input − Output (1.1)

The site water balance must include details of [3]:

- Sources and security of water supply
- Water uses on-site
- Water management on-site
- Off-site transfers

Tables 2.1 and 2.2 are lists of inputs and outputs with their corresponding sources respectively.

Table 1. List of inputs with their corresponding destinations [4]

Source	Input
Surface	Precipitation and Runoff
	Rivers and Creeks
	External Surface Water Storages
Groundwater	Aquifer Interception (Dewatering)
	Bore Fields
	Entertainment
Sea Water	Estuary
	Sea/Ocean
Third Party	Contract/Municipal
	Waste water

Table 2. List of outputs with their corresponding destinations [4]

Destination	Output
Surface	Discharge
	Environmental Flows
Groundwater	Seepage
	Reinjection
Sea Water	Discharge to Estuary
	Discharge to Sea/Ocean
Supply to Third Party	
Other	Evaporation
	Entertainment

3. Fieldwork

The main sources of water for EGM are the Asuafa stream – a stream that passes through the mine site, rainfall, mine water impoundments, and groundwater. The major water demands or losses within the mine water management system are in ore processing, dust suppression, evaporation, seepages and other losses. The off-site transfers include the discharge of groundwater from pits. Water from pit dewatering is first discharged into silt traps arranged around the mine site. Much of this water is reused on site, whereas surplus water is treated and discharged back into nearby rivers. The quality of water collected in the silt trap is monitored to ensure that it meets Environmental Protection Agency (EPA) standards before discharging into the environment.

The infrastructure components within the mine water management system include the Process Water Pond (PWP) for storing water to serve as process water supply, the Flotation Tailings Storage Facility (FTSF) for collecting flotation tailings and recovering water to serve as process water supply, the CIL Tailings Storage Facility (CTSF) for collecting the CIL tailings and for recovering water to serve as process water supply, the Water Treatment Facility (WTF) for purifying groundwater extracted as potable water and treating return water from the CTSF, and finally, transfer pumps and pipelines.

4. Results and Discussion

Monthly data based on daily recordings were collected for the entire year, 2012. The quantity of water in river, dam, and ponds were estimated based on the length, width and depth of the structure concerned.

The following water data were collected for the year 2012 and used in the analysis:

- The quantity extracted from each source.
- The quantity used within each operation.
- The quantity lost due to evaporation.
- The quantity discharged off-site.

The different structures and quantities associated with the water balance are shown in Fig. 2.1. Table 2.1 summarizes annual net water balance estimation.

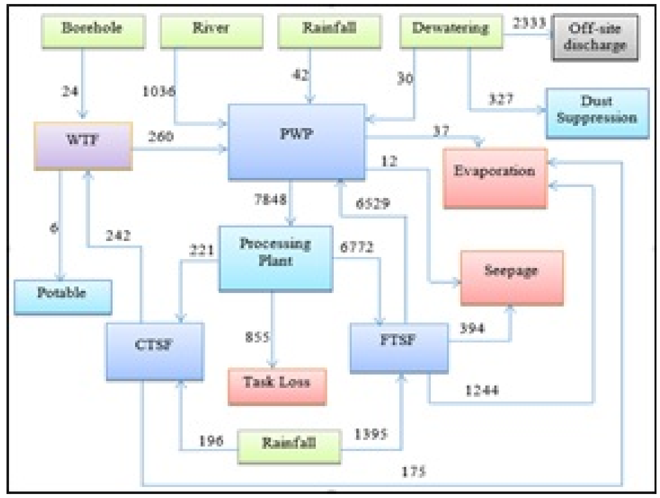

Figure 1. Site water balance framework (values are in × 1000 m^3)

Table 3. Water balance summary for 2012

Item	Quantity per annum
Rainfall on Dams and Ponds	1633000m³
River	1036000m³
Borehole Water	24000m³
Groundwater (Dewatering)	2637000m³
Retention Pond (Lily Pond)	53000m³
Water Outputs	
Evaporation from Dams and Ponds	1456000m³
Seepage	406000m³
Dust Suppression	327000m³
Discharge Off-ate	2333000m³
Summary	
Gross Water Input	5383000m
Gross Water Output	4522000m³
Net Water Balance	861000m³

The tasks and storages on the mine considered include the Concentrates Tailings Storage Facility (CTSF), Flotation Tailings Storage Facility (FTSF), Water Treatment Facility (WTF), Process Water Pond (PWP), and Processing Plant. The inputs and outputs with associated flow volumes are also captured in Fig. 2.1. The difference between the total annual water input and total annual water output resulted in the annual net water balance of 861,000 m^3 as shown in Table 2.1.

5. Conclusion

After analyzing data collected from various mine tasks, the following conclusions are drawn:

- The main sources of water for the mine are rainfall and the Asuafa River.
- The processing plant is the main water user on the mine and effective use of water at the processing plant is key to storing water for future use.
- Storage capacities are established based on the calculated net water balance of 861,000m^3.

6. Recommendations

Based on the results of the study, the following suggestions are deemed vital for solving future water- related challenges at Edikan Gold Mine (EGM):

- Water management must be incorporated into the day-to-day business objectives of the mine.
- Clear accountabilities for water consumption and usage in every department must be done daily and then collated together by a coordinating body to ascertain the actual monthly and annual consumptions.
- Appropriately sized water storage facilities should be built based on the calculated net water balance for storing excess water for use during drought conditions.
- An up-to-date and well managed information and monitoring system should be established to store and analyze site water data.

7. Acknowledgement

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