SUBMERGE BARRIER
AS A SEDIMENT TRAP IN A RESERVOIR

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ABSTRACT

Sediment deposition and accumulation through the reservoir bed causes problems in the shortage and utilization of surface water as well as subsequent decline of reservoir economic and useful lifetime. The economic life time of a reservoir is defined as the time necessary for aproximately 100% of the initial dead storsge capacity to be filled with incoming sediment. While useful lifetime may be defined as the period in which a reservoir is still functioning even beyond the economic lifetime. Sediment barrier placed at reservoir bed affect the inflow pattern and, thus, intensify the increase of volume of sediment trapped before the sediment flow reach the reservoir dead storage. The purpose of this study is to investigate the effect of a submerge barrier on sediment deposition at the reservoir bed. The case study is Bakaru Reservoir located in Mamasa River, South Sulawesi, Indonesia. For this purpose, an experiment was carried out in Bakaru reservoir model with highly sedimented inflow "with" and "without" submerged sediment barrier. The model considers the factors affecting the reservor sedimentation and trap efficiency. The amount of sediment retained in the submerged barrier as the results of sedimentation was measured and compared with that retained without submerged barrier. The results obtained revealed that the submerged barrier improved the volume of sediment retained and thereby improve the reservoir trap effeciency. Since the sediment retained located outside and upstream of the dead storage, the sediment is easily dregged out without interfering the reservoir operation, thus, will increase the economic and theservice life of Dams.

KeyWords*: Reservoir sedimentation, Trapefficiency,Submerge Sedimentbarrier.*

1. INTRODUCTION

Bakaru Dam is a vital infrastructure for South Sulawesi, socially and economically. The main purpose of the dam is to preserve water for hydropower generation. It was constructed to utilize the Mamasa river flow throught the year with a daily pondage reservoir. The original storage capacity was 6.90 million m3 including 2 million m3 effective storage. The main function of the reservoir is a hydropower generation which was planned in two stages.The first stage was completed in 1990 with 2x63 MW installed capacity. The daily pondage was designed to accommodate the effective storage capacity to securely supply water during peak time of 6 hour a day for four generating units (stage I and stage II). The dam is located on Mamasa River, South Sulawesi, Indonesia.

The study area is characterized by tropical moonson climate, with an average annual temperature of 25.5°C and precipitation of 2,300 mm. The Mamasa River has a nturaldarainage area of 1080 km2 and a total length of 126 Km, originating from the North of Mt. Paraleang at Polmas, passing through Pinrang, and joins the Sadang River at Temban, Enrekang. The Mamasa riverbed slopes are; 1:120 for upstream section, and 1:1400 for the downstream of the Bakaru Dam respectively.

Bakaru dam, which was constructed during the period of 1989 – 1990, is a concrete gravity dam with four spillways, two sand drains, and two control gates. The dam and the power plant are in good condition. The power plant has been operated since then with an average power production of 990 GWh per annum. Dead storage capacity 4,900,000 m^3, effective storage capacity 2,000,000 m^3, and gross storage capacity 6,900,000 m^3.Low Water Level (LWL) EL. 612 m and Normal water Level (NWL) EL. 615 m.The reservoir however, has been subjected to severe sedimentation making the situation crucial for the implementation of Bakaru Stage-II. The original sediment rate estimate was 133,000 m^3/year. In fact, bathimetric survey in 1996 found the sediment accumulated amount to 6.20 million m3, thus, the effective storage left only aout 700,000 m3. Furthermore, the sedimentation causes deterioration of the metal equipment such as guide van, runner, penstock, and the cooling system components.

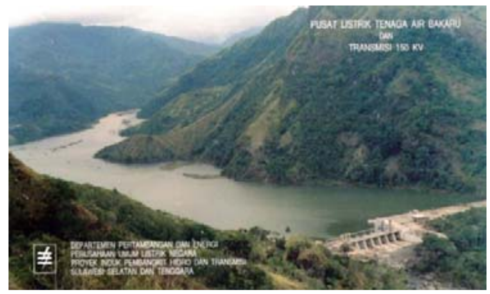


Fig-1.Bakaru Reservoir (1991)

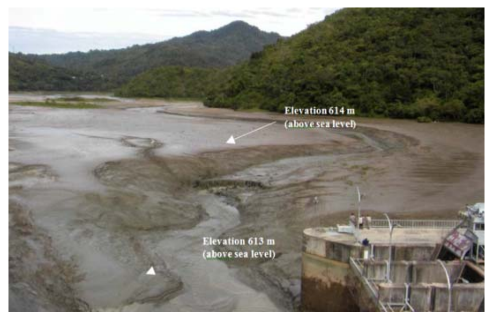


Fig-2. Sediment Accumulation (2008)

Today, average annual sediment inflow is about 700 to 800 thousand m^3. This makes severe reduction the reservoir storage capacity.

Table-1. The current condition of the System

Description	Unit	Original Design	Current Condition
− Reservoir capacity	M^3	6.92×10^6	0.8×10^6
− Annual sedimentation	M^3/year	0.13×10^6	0.75
− Effective reservoir	m^3	2.00×10^6	0.70×10^6
− High water level	m	615.50	615.50
− Low water level	m	612.00	613.00
	GWh/yea	999	850
	MW	2 x 63 2 x 63	2 x 63 not

− Energy production − Installed capacity o Stage I o Stage II	MW		impleme nted yet

Source: CompletionReport Bakaru2nd Stage, PLN.

Flushing and dredging have been performed since year 2000 but little change to the sediment accumulated infront of the dam. The excess sediment inflow into Bakaru Reservoir has been deteriorating the dam functions for hydropower generation of 126 MW. The table below shows the current condition of the system.

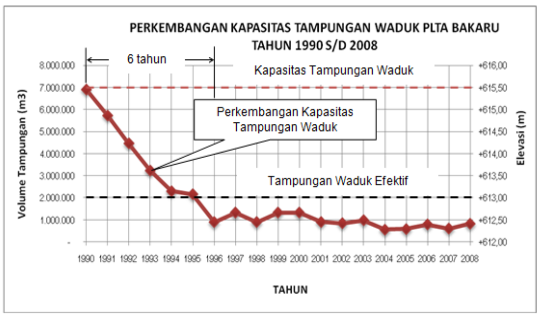


Fig-3.Reservoir Capacity Reduction (MS.SofanHadi, 2011)

The main objective of the study is to find the effect of submerged barriers on sediment distribution along the Bakaru reservoir bed and to look for effective and economical measures for reservoir sediment reduction and removal.In order to secure the dam functions, both structural measures and proper sediment management measures are required.

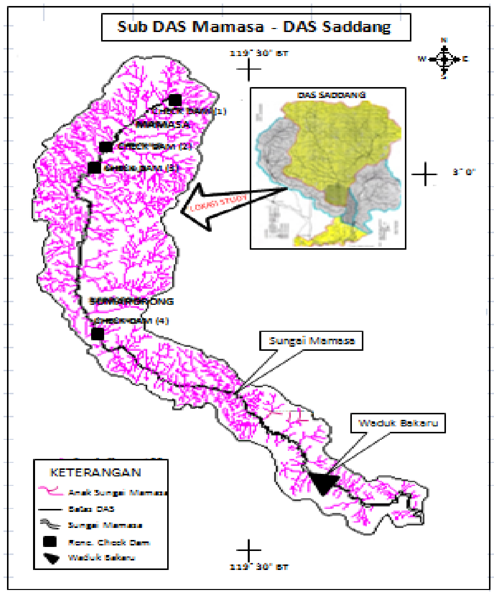
2. BAKARU RESERVOIR SEDIMENTATION

General.

Bakaru SedimentationHistory

Globally, most of reservoirs, have been affected by sedimentation. Some of them are filled very seriously affected (CT.Yang, 2000). The overall annual loss rate of reservoir storage capacity due to sedimentation is estimated as 1 to 2 percent of the total storage capacity (Yoon, 1992; Yang, 2003). As for Bakaru Reservoir case, the sedimentation becomes a serious problem as it decreases the storage capacity and, hence, makes the structure less efficient and delay of the second stage plan of 2x63 MW.

In the Mamasa Sub-Catchment , runoff caused by rainstorm mainly occurs in rainy season, from April to September, therefore, the sediment is mainly concentrated in flood season. Sediment in the Mamasa river is originating from the upper reaches with large quantities of eroded soil. This stems from frequently alternating drought-rainy seasons. These are resulting in loosening of the soil surface thus facilitating and accelerating water erosion.



Therefore, it leads to land degradation in the upper reaches, sedimentation in lower reaches and loss of reservoir's capacities, abrasion of turbine and other components of hydropower mechanical componenent such as cooling system. On the other hand, sediment results from soil erosion due to deforestation, human activities, and land-use mismanagement.

Bakaru reservoir sedimentation is the process of sediment deposition formed after the dam construction in 1990. The dam caused the flow water impoundment, flow velocity reduction, turbulence, and consequently the settling process of sediment carried by the Bakaru river inflows. Measurement of the sedimentation in the reservoir were carried out by PT.PLN starting from 1994 to date except in 1998, 2003, and 2004 due to the less of inflow. The sedimentation history of the reservoir is shown in figure below.

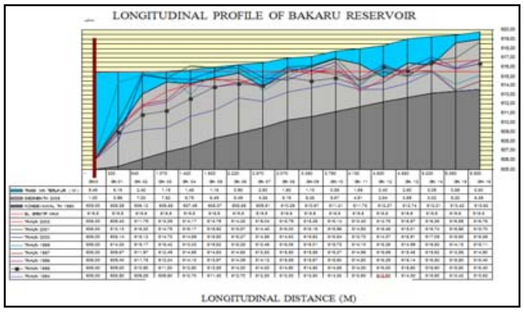


Fig-5.Sedimentation History of Bakaru Reservoir, PT.PLN 2012.

Table-2. Flushing and Dredging of Sediment

Time	Volume (m^3)	Notes
04 February 2000	893,465	Year 2003 and 2004 Flushing not conducted due tominimum discharge available.
09 April 2001	256,840	
05 September 2001	187,722	
02 May 2002	543,429	
07 September 2005	162,000	
16 January 2006	613,374	
2007 to 2011	200,000-500,000	Average

Source: PT. PLN Sul-Sel-Bar, 2012

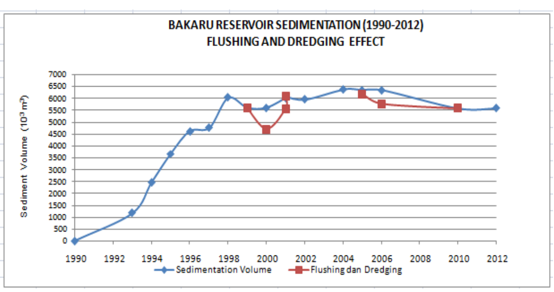


Fig-6. Flushing and Dredging Effect

As the useful life of a reservoir directly depends on the reservoir sedimentation accumulation and reservoir economic lifetime becomes the vital target of all reservoir development make the issue as an important subject within reservoir planning and design as well as reservoir operation and maintenance. On the aspect of sediment control practice, the lost storage volume due to sedimentation can be recovered by use of the sediment-removal methods such as: sluicing; dredging by mechanical means; jetting with high velocity jets; draining the reservoir completely and hauling the material by trucks, or others kind of transportation;(RANGA and RAJU, 1985).

Reservoir sedimentation can also be significantly reduced by construction of by-pass channel such as siphon and sluice to divert flows with high sediment concentration to the river downstream. Siphoning can be an effective method for removing sediment from a small reservoir. However, blockage in the pipeline, hydraulic head available, and pipe length could limit the use of this method. Sluicing of sediment may be an effective method to discharge reservoir sediment if the low level outlet works have sufficient capacities and the reservoir is relatively narrow, [YANG, 1996].

Theoritically, the useful life of a reservoir can be preserved by minimizing sediment deposit and maximizing sediment outflow through the reservoir. This paper presents the issue of Bakaru Reservoir sedimentation with emphasis on introduction of submerge barrier for sediment handling measure. This paper introduce the use of submerge barrier as a countermeasure for Bakaru Reservoir sedimentation problem.

3. OVERVIEW OF SEDIMENT MANAGEMENT METHODS

Avalable Methods

The methods available for managing sediment in reservoir can be grouped into the following four categories:

a. Minimize Sediment Entering Reservoir. This includes Watershed management, Upstream trapping, Locate reservoir off-stream, Preserve, Enhance, Restore, and Construct wetlands.

b. Minimize Deposition of Sediment in Reservoir. This includes: Sediment pass-through, Density current venting, Sediment bypass, Hydrosuction bypass.
c. Remove Sediment From Reservoir. This includes: Flushing, Excavation, Dredging, Hydrosuctiondredging.
d. Compensate for Sediment Accumulation in Reservoir. This includes: Enlarge dam, Decommissioning of dam, and Construct a new dam.

Submerge Sediment Barrier Method

As mentioned above, various methods can be applied to solve, or at least, to reduce reservoir sedimentation problems. Excavated SubmergedBarrier is a measure to reduce sediment load to a dead storage. It is a sediment trapping method to be introducedto sedimen management. The barrier consist of excavated channels layed a cross the reservoir bed. The lower end of the barrier is connected to a sediment pool outside the reservoir. The principal function of the barrier is trapping sediment laden and drain it to a temporary sediment pool. A part of the sediment will accumulate in the pool while the cleaner water flows back to the reservoir.Figure-7 shows the barrier layout.

Their purpose is to reduce the sediment load to a maximum possible level to maintain low sediment accumulation in the the reservoir bed or in the dead storage. To attain this goal, the barriers are designed to allow trapped sediment to travel along the channels and deposit at sediment pool. Since the sediment accumulated in the pool outside the reservoir it can be easily removed by dredging or other simple measures. The sediment will finally be removed to disposal area.

Based on the above categories submerged barrier method may be classified into either minimize deposition of sediment or remove sediment from the reservoir categories.

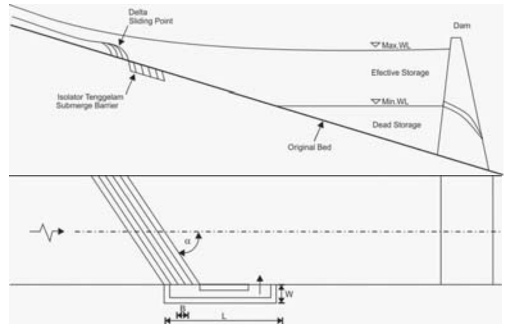


Fig-7.Submerge Barrier Layout

As for Bakaru reservoir sedimentation problem, the submerge barrier method is applied to Bakaru Reservoir model to test how the barrier control the sediment inflow and extend the useful life of the reservoir and to help sustain the vital benefit from the electric power generation produce by the reservoir

4. MATERIAL AND METHOD

This study is designed to simulate the relationship between sediment inflow and the sediment retained by submerge barrier with use of Bakaru Reservoir model. To attain the purposes, an effort was made to collect existing background data pertaining to the study area, BakaruReservoir, andBakaruDam Site. Data Mining consists of data collection, preparation, and modeling. The major source of recent bathymetry data was the 1996-2011 survey of the River System by the State Electric Company (PLN) and Hasanuddin University (UNHAS). Hydrologic and Sediment data were obtained from PLN.Daily flow basis data record are available at Bakaru Dam Control Office.

In order to obtain favourable results from the hydraulic modeling, a physical model of Bakaru Dam was made. Parts of the prototype reproduced in the model were the dam, spillway, intake, and their parts and were made according to the survey results. The similarity in shape, dimensions and roughness of the material in the prototype were observed. The shape and measurements reproduced in the model are the shape and hydraulic measurement that influence the surface flow pattern. The model of weir, outlet gate, and their parts were made considering common designs.The similarity in shape, dimensions and roughness of the material in the prototype design were simplified.

5. RESULTS, DISCUSSION, AND CONCLUSION

Results

Bakaru reservoir has been developed in undistorted model with a scale of n:150.
The model includes Mamasa river portion, Bakaru Dam, intake gates, drain inlet gates, and the submerge barrier. Preliminary tests were conducted. The first run was to test how sediment distributed along the reservoir bed and the volume of sediment trapped without submerge barrier.

Fig-8.Bakaru Reservoir Model and Sediment Deposited At Submerged Barriers

The second run was to test how the submerge barrier affect the sediment trapped. The two experiments showed promising results. Figure-8 below show the experiment results.

Observation obtained from the run-tests showed that the effect of series submerged sediment barriers on sediment trapping has been very good. The test with submerged barriers trapped about 10% more sediment compared to the test without barriers.

Discussion

In the case of this experiment, the effectifness of the submerged barrier is defined as the ratio of the sediment trapped before and after the set up of the barriers. Since the results showed an increase on sediment trapped after the set up of the barriers, it can be expected that the series submerged barriers decresed the inflow velocity and hence, increase the fall velocity of the sediment particles. Accordingly, more sediment deposited at the barriers area compared with that have accumulated before the set up of the barriers.

In summary, the submerged barriers affect the inflow pattern and the sediment deposition on the reservoir bed by trapping more sediment and, hence, reduce sediment inflow to the dead storage. Therefore, there is potential measurement to remove the sediment from reservoir without interfering the reservoir operations. Accordingly, it may be expected that the sediment removal will be inexpensive and economic and useful lifetimeof reservoir will be increased.

In order to optimize the barrier performance and to trap as much sediment as possible, more tests are required to evaluate the sediment inflow characteristic and its parameters, the sizes, numbers, and dimensions of the barriers, as well as the best fitted location for the barriers system plan. This may significantly improve the system adequacy.

Preliminary Conclusions`

The effect of submerged barriers on sediment deposition was evaluated in Bakaru Reservoir Model. The preliminary key findings of the experiment are as follows:

a. The series of submerged sediment barriers increased the volume of sediment trapped.
b. The sediment trapped accumulated at the barriers and, therefore, the volume of sediment deposited in the dead storage has been less.
c. Since the sediment deposit accumulated at temporary sediment pool outside the reservoir, the removal of the sediment would be simple and economical.

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