The Study of Sedimentation at Jongkong Reservoir in District Central of Bangka through Erosion of Catchment Area

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Abstract. Jongkong reservoir creates a reservoir of water that is used for the purposes of raw water as fundamental media for improvement of drinking water production especially at dry season for the District of Koba. The advantage of being able to hold water in wet season and releasing it in dry season will be detained if the life storage of the reservoir can be utilized effectively, but sedimentation problem will decrease its volume which can influence the lifetime of reservoir. Finally the reservoir becomes less effective, so it is very important to study. The method which is used to predict an average erosion rate in the catchment area considers factors of rain erosivity, soil erodibility, ground inclination of slope or slope length, management of crop and land, soil conservation. Calculation was done by using the USLE equation (Universal Soil Loss Equation) which was developed by Wischmeier and Smith (1965, 1978). From this research result, the prediction of surface erosion rate in the basin catchment area in the year 2019 is equal to 53.20 mm/year or equivalent with 62,491.92 m$^3$/year, and the value of Sediment Delivery Ratio (SDR) is equal to 32.28 %. The number of material which eroded is equal to 957.59 Ton/Ha/year so it is classified into the medium erosion class category. The dead storage of 5% of the the volume of the reservoir cage will be fully charged in the year 2022 or for 3 The next year and the total volume of the reservoir Ridge will be full of sediment in the year 2062 or 43 years.

1. Introduction
Jongkong reservoir creates a reservoir of water that is used for the purposes of water raw as fundamental media for improvement of drinking water production especially at dry season. Beside that, Jongkong reservoir also used for the drinking water to district central of Bangka. The investment of reservoir construction need a lot of money, hence the economic calculation of reservoir construction becomes important. Jongkong reservoir as water resources of former tin mining the potential to utilize. Yet the utilization of water has not been managed based on the principle of reliability value. The advantage of being able to hold water in wet season and releasing it in dry season will be detained if the life storage of the reservoir can be utilized effectively, but sedimentation problem will decrease its volume which can influence the lifetime of reservoir. All reservoirs formed by former tin mining that existed on the island of Bangka in the past that formed water reservoirs, both from groundwater flow and the flow of rainwater that enters the reservoir naturally will become targets for soil erosion and sedimentation. To reduce the sedimentation rate, soil erosion analysis needs to be done, so that the catchment areas that have a high level of erosion hazard can be identified, so that the direction of mitigation can be carried out. Finally the dam becomes less effective, so it is very important to study.
2. Literature Review

Puji Utomo (2017) topic research is Mrica Reservoir Sedimentation: Current Situation and Future Necessary Management [1]. The results show that during the last decade, the rate of the sediment inflow was approximately 5.869 MCM/year, whereas the released sediment from the reservoir was 4.097 MCM/year. In order to maintain the reservoir capacity, therefore, at least 1.772 MCM/year should be released from the reservoir by means of either flushing or dredging. Sedimentation management may prolong the reservoir’s service life to exceed the design life. Without sediment management, the lifetime of the reservoir would have finished by 2016, whereas with the proper management the lifetime may be extended to 2025.

C.Tundu, M.J.Tumbare and J.M.K. Onema (2018) topic research is Sedimentation and Its Impacts/Effects on River System and Reservoir Water Quality: case Study of Mazowe Catchment, Zimbabwe [2]. Tundu used to method the Revised Universal Soil Loss Equation (RUSLE) model for calculate soil erosion of Mazowe catchment. The result research concluded that erosion and sedimentation can affect the water quality of water sources of Mazowe Catcment Zimbabwe.

Umesh C. Kothyari (1983) topic research is Erosion and Sedimentation problems in India [3]. The problem of soil erosion is prevalent over about 53% of the total land area of india (Narayana & Ram Babu, 1983). The regions of high erosion include the total land area of India and Himalayan regions have been greatly affected by soil erosion due to intensive deforestation, large scale road contraction, mining and cultivation on steep slopes [4]. Surveys of existing lage and medium-sized Indian reservoirs have indicated that at least six lage resevoirs (storage>100 Mm$^3$) and three medium-sized reservoirs (storage 20-100 Mm$^3$) have already lost more than 25% of their capacities [5] (Morris, 1995; Shangle, 1991). In the present paper many data related to erosion and sedimentation problems in India are presented. Qualitative analysis of these data is also undertaken to identify the prossible causes of intensive erosion and sedimentation [6].

3. Theoretical Consideration and Methods

3.1. Research Methodology

The method used to predict the average rate of erosion in the catchment area by taking into account the erosivity factor of rain, erosive soils, slope slope or long slope, crop management and soil conservation, each of which can be made maps. In the calculation analysis is done using the USLE equation (Universal Soil Loss Equation) developed by Wischmeier and Smith (1965, 1978) [7]. To determine the prediction of the magnitude of erosion rate required collecting some necessary data before conducting the analysis. The data include: Earth image map, rainfall data, land type map, land use data, Obervasi, echosounding field measurement results and other supporting literature. Predictably the average erosion rate of a particular land area, on a steepness slope and with certain rain patterns

3.2. Rain Erosivity Factor ($R_m$ Factor)

Rainfall data was processed into average annual rainfall. Rain erosion was calculated from the from the rain stations that are influential in the catchment area of Jongkong, i.e. stations; BMKG Depati Amir Pangkalpinang, each from 2008 to 2018 using Eq.

$$R_m = 2.21 P_m^{1.36}$$

where: $R_m$ = Rain Erosivity Factor, $P_m$ = mean Annual Rainfall (cm).

3.3. Soil Erodibility Factor ($K$ Factor)

The soil erodibility factor ($K$ Factor) was calculated using Obtained from the management hall of the river basin and the protected forest (BPDASHL) Baturasa Cerucuk Province of Island Bangka Belitung, 2019, for conditions of soil type present in the research site as in Table 1.
### Table 1. Soil Type and Soil Erodibility Factor (K)

| No. | Soil Type                                                                 | K Factor |
|-----|---------------------------------------------------------------------------|----------|
| 1   | Latosol Brown                                                            | 0.16     |
| 2   | Latosol red yellowish, red yellow Podosol                                 | 0.56     |
| 3   | Red-yellowish Podosol complex, yellow-Regusol Podosol                    | 0.53     |

### 3.4. The Topographic Factor (LS Factor)

Steeper slopes produce higher overland flow velocities. The topographic factor (LS) will result in increased erosion potential while for the determination of the LS factor follows the class of slope assessment issued by the Forestry Department [8] as in Table 2.

| Class | Slope (%) | LS |
|-------|------------|----|
| I     | 0 – 8      | 0.4 |
| II    | 8 – 15     | 1.4 |
| III   | 15 – 25    | 3.1 |
| IV    | 25 – 40    | 6.8 |
| V     | > 40       | 9.5 |

### Table 2. The Topographic Factor (LS) (Departement of Forestry, 2009)

### 3.5. Land Cover and Crop Management Factor (CP Factor)

The value of crop management factor (C), and land cover (P), are obtained from the C factor table based on land use maps. Land use maps obtained from the Digital Earth image map issued by Bakosurtanal combined with the land use map issued by the Municipal Management Hall of the River and Protection Forest (BPDASHL) Baturusa Cerucuk Islands Province The Bangka Belitung.

### 3.6. Erosion in the Catchment

The prediction that still popular and commonly used for average erosion rate from the certain watershed is the Universal Soil Loss Equation (USLE) by Wischmeier and Smith (1965, 1978) method with its various modifications and development, which is as follows:

\[
A = R \times K \times L \times S \times C \times P
\]

where \( A \) is the amount of soil loss (ton/ha/year or mm/year), \( R \) is the rainfall factor, \( K \) is the soil type factor, \( L \) is the slope length factor, \( S \) is the slope gradient factor, \( C \) is the soil vegetation cover and crop management factor, and \( P \) is the land conservation special treatments factor. Based on prediction with USLE method, the total of soil loss in an erosion process would determine a danger level of erosion in a watershed, as seen in Table 1. The previous study on the estimation of the catchment erosion of Jongkong Reservoir (applying USLE method for 2009 to 2018 rainfall data) has found the average annual catchment erosion.

### Table 3. Classification of Erosion Danger Level (Departement of Forestry, 2009)

| Erosion Danger Level | Soil loss (A) in (ton/ha/year) | Note    |
|----------------------|-------------------------------|---------|
| I                    | <15                           | very light |
| II                   | 15 - 60                       | light    |
| III                  | 60 - 180                      | medium   |
| IV                   | 180 - 480                     | heavy    |
| V                    | >480                          | very heavy |
3.7. Quantifying The Sediment Yield in The Catchment

Soil loss from the catchment cannot be taken as sediment contribution to a river flow system since it does not account for deposition that occurs along the path (de Vente et al., 2011). Therefore the estimated soil loss was multiplied by the sediment delivery ratio (SDR) to obtain the sediment yield of the catchment. Sediment delivery ratios represent the fraction of the total soil loss that is washed into rivers and was calculated from using Eq. (3) (USDA, 1972) [9].

$$ SDR = 0.5656CA^{-0.11} $$

Where: $SDR$=Sediment Delivery Ratio; $CA$=Watershed Area, km$^2$.

After determination of the sediment delivery ratio, the average sediment yield was determined using Eq. (4), by Wischmeier and Smith (1978).

$$ SR = SDR \times A $$

where: $SR$=Sediment yield (t ha yr); $SDR$=Sediment delivery ratio; $A$=Average soil loss (t/ha/yr).

4. Result and Discussion

4.1. Description of Measurements

Characteristic measurement of reservoir in the area of water catchment areas, the depth of reservoir, the volume of the reservoir, the surface area of the sea is obtained by analyzing the contour map result of processed GPS measurement data and Sounding UAV (Ecosounder remote sensing) with Computer software (software) MapInfo and ArcView GIS. The measurement results showed the surface area of 10.4411 Ha and the volume of paste 850,614.1 m$^3$.

**Figure 1.** The measurement results showed the characteristic surface area of the Jongkong Reservoir and the depth using Ecosounder remote sensing.

Based on Figure 1. The results of the analysis showed the deep depths of Jongkong reached 19.20 m while the water surface area of 135,800.00 m$^2$. The shape of the curve of relations between a reservoir Jongkong variable trendline estimation results and a regression analysis shown in Figure 2.
Figure 2 can be seen equation of a reservoir (m) relationship to the volume of the Paste (thousand m\(^3\)) is
\[ V = 0.1104x^3 + 0.1283x^2 + 2.5474x - 0.9714 \] ..............................(5)
where \( V \) = volume of reservoir (thousand m\(^3\))
\( x \) = the elevation of reservoir (m)

against the area of the puddle (Thousand m\(^2\)) is
\[ L = 0.0061x^3 + 0.1682x^2 + 1.4471x + 0.5111 \] ..............................(6)
where \( L \) = area of puddle (thousand m\(^2\))

Field measurement results shows the average high depth of sediment of 4.20 meters so that from the Equation 6 in the get sedimentation in the Jongkong reservoir 2019 of 20,170.21 m\(^3\)

4.2. Rain Erosivity Factor Analysis (Rm)
Rainfall data was processed into average annual rainfall. Rain erosivity was calculated from the from stations; BMKG Depati Amir Pangkalpinang, each from 2009 to 2018. The maximum rain erosivity value occurred in March of 212.96 mm, while the minimum rainfall erosivity occurred in September of 38.89 mm
4.3. Soil Erodibility Factor (K Factor), The Topographic Factor (LS Factor), Land Cover and Crop Management Factor (CP Factor)

The soil erodibility factor (K Factor), land cover and crop management factor (CP Factor) was calculated using Obtained from the management hall of the river basin and the protected forest (BPDASHL) Baturusa Cerucuk Province of Island Bangka Belitung, for conditions of the topographic factor (LS) type present in the research site as in Figure 4.

![Figure 4. Characteristic of Catcment Area at Jongkong Reservoir in District Central of Bangka](image)

Land use in the catcment area of jongkong reservoir at figure 4 shows that Shurbs amounting to 37.52 ha with a value of K factor = 0.56, LS factor =1.4, C factor = 0.3 and P factor = 1, while for the plantation of 7.45 ha with the value of K factor = 0.56, LS factor = 3.1, C factor = 0.4 and P factor = 1, then for the area wasteland of 51.91 Ha with a value of K factor = 0.16, LS factor = 6.8, C factor = 1 and P factor = 1. For land use of amounted forest 20.59 Ha with a value of K factor = 0.53, LS factor = 0.4, C factor = 0.001 and P factor = 1.

4.4. Erosion in The Catchment

After the calculated overall from January to December the amount of surface erosion was obtained annually as in Table 4. and erosion rate maps as in Figure 4.

| Month | Land Area (ha) | Erosion Ton/Month | Erosion mm/Month |
|-------|----------------|-------------------|------------------|
| Jan   | 117.47         | 11,249.87         | 5.32             |
| Feb   | 117.47         | 12,013.51         | 5.68             |
| Mar   | 117.47         | 15,009.58         | 7.10             |
| Apr   | 117.47         | 11,480.01         | 5.43             |
| May   | 117.47         | 10,139.24         | 4.80             |
| Jun   | 117.47         | 7,445.89          | 3.52             |
| Jul   | 117.47         | 5,127.06          | 2.42             |
| Aug   | 117.47         | 4,136.11          | 1.96             |
| Sep   | 117.47         | 2,740.96          | 1.30             |
| Oct   | 117.47         | 6,941.71          | 3.28             |
| Nov   | 117.47         | 11,775.91         | 5.57             |
| Dec   | 117.47         | 14,425.62         | 6.82             |

| A (ton/year) | 112,485.46 |
|--------------|------------|
| A (ton/ha/year) | 957.59 |
| A (mm/year) | 53.20    |

*) By taking a heavy value of sedimentary mass/soil $\gamma = 1.8$ Ton/m$^3$
From the calculation of the analysis of Table 4 it appears that the surface erosion rate in the sea-catchment area Jongkong is large enough, reaching 53.20 mm/year or 957.59 tons/Ha/year, resulting in surface erosion (A), or the average erosion occurring in the catchment area of Jongkong reservoir can be classified into a medium erosion hazard class (class III).

This considerable erosion rate is made possible by the transfer of land use function that has not been in accordance with the function and utilization of land that has been determined by the government. For example, the area that serves as a forest turned into tin mining area. This will greatly affect the amount of erosion rate, when the planting is done if the slope is very steep in large quantities.

Another reason may be due to the unbalanced population density that will be positive towards the ability/support of conservation land, considering the increase in population compared to the upside of the area/land. Consequently there will be an expansion of land that will indirectly disrupt land conservation. The amount of surface erosion donors according to the land use is shown in Table 5.

| No | Land Use | Area (Ha) | Area (%) | A (Tons/Ha/Year) | A (Ton/Year) |
|----|----------|-----------|----------|------------------|--------------|
| 1  | Shrubs   | 37.52     | 31.94    | 375.38           | 14,083.04    |
| 2  | Plantation | 7.45     | 6.34     | 1,108.26         | 8,253.31     |
| 3  | Wasteland | 51.91     | 44.19    | 1,736.44         | 90,142.15    |
| 4  | Forest   | 20.59     | 17.53    | 0.34             | 6.97         |
|    | Total    | 117.47    | 100.00   | **957.59**       | **112,485.46** |

From the results of Table 5 analysis showed that the biggest erosion contributor is from an open ground land (Wasteland) used by tin mining, which reaches 90,142.15 ton/year. The value of surface erosion rate of 53.20 mm/year is equivalent to the magnitude of erosion of 62,491.92 m³/year (by taking the heavy value of sediment/ground time of $\gamma = 1.8$ ton/m³). Erosion value of 53.20 mm/year This is certainly not all will go directly into the jongkong reservoir, but some will be held in the surface/land.

4.5. Quantifying The Sediment Yield in the Catchment and Sedimentation at Jongkong Resevoir

The comparison of sediments that enter into the reservoir with a sediment that is erosion is named as the sediments Delivery ratio (SDR). SDR value can demonstrate the effectiveness of existing erosion control systems, including land use and soil conservation. The smaller SDR value means the more effective erosion control system, and vice versa. SDR value for a reservoir Jongkong is obtained by dividing the magnitude of the sedimentation occurring in the ground of Jongkong with predictions of the magnitude of surface erosion occurring in the catchment area (the result of the USLE formula count). By using the data echosounding measurement conducted by the researcher, indicating the value of sediment that entered into its defence is 20,170.21 m³/th. So SDR value for a reservoir Jongkong is; $SDR = (20,170.21 \div 62,491.92) = 0.3228$ This would mean that 32.28% of the surface erosion that occurred (USLE formula results) would go into the Jongkong's reservoir, while the remaining 67.72% would be left on the ground. Whereas SDR according to theory by USDA, 1972 was obtained $SDR$ results by 0.5557 or 55.57%.
Figure 5. Erosion, Sedimentation of SDR 55.57% and Sedimentation of SDR 32.28%

The larger slope of SDR in the catchment area Jongkong generally has a relatively large tilt slope. 44.19% of the catchment area has a topographic factor (slope) of more than 20%, or in the category class III. In addition to the land use factors can still be a lot of inhibiting or slowing run off, so with an SDR value of 32.28% can be deduced land use is currently not effective for existing erosion control systems.

Given that the surface erosion is included in the medium category, it is necessary to reduce the rate of erosion that is still possible to apply, among others, improvements to the open ground of the former tin Mining for conservation. Assuming the sedimentation rate is based on the 2019 measurement result of 20,170.21 m$^3$/year and without any handling, dead storage will be fully charged in the year 2022 or 3 years in the future dead storage will be fully charged due to the sedimentation caused Erosion of the catchment area. And the total volume of the reservoir Ridge will be full of sediment in the year 2062 or 43 years.

5. Conclusion
The erosion rate that occurred in the land-catchment area of Jongkong is based on the conditions of soil use from the map of the classification of medium erosion hazard class or class III category, which is 957.59 Ton/Ha/year or 53.20 mm/year, equivalent to 62,491.92 m$^3$/year. The amount of Sediment Delivery Ratio (SDR) is 32.28%, comparing the number of sediments that went into the reservoir of 20,170.21 m$^3$/year from the results of field measurements with echosounding. Assuming based on the sedimentation rate of the 2019 measurement result of 20,170.21 m$^3$/year and without significant land use change, the dead storage of 5% of the the volume of the reservoir cage will be fully charged in the year 2022 or for 3 The next year and the total volume of the reservoir Ridge will be full of sediment in the year 2062 or 43 years.

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