Evaluation on sabo dam construction planning Matakabo River at East Seram island

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Abstract. The Matakabo River is one of the major rivers in Maluku Province that crosses the Eastern Seram Regency. The Matakabo River is currently used for the Matakabo Irrigation Area through Matakabo Weir, with an area of + 3,050 Ha. Considering the number of tributaries entering the Matakabo River system and the risk of changes in land conversion in upstream, the development of Sabo Dam is seen as crucial for securing the water supply to irrigation as well as functioning as flood control. The location of 6 Sabo Dam is in Wai Sop, Wai Mol, Wai Sol, Wai Bemisi, Wai Jana, and Wai Ines areas based on visuals in the field where these areas are vulnerable to erosion and sedimentation. The calculation of flood discharge uses two methods, namely Nakayasu and ITB. Based on the highest river flow and flood capacity in the Q₂: 401.68 m³ / second field which is close to the results of the synthetic discharge calculation from the ITB Method. Evaluation of 6 Sabo Dam with 1 Groundsill in Matakabo based on the calculation of the Van Rijn and Meyer Peter Muller (MPM) method will be able to accommodate sediment beds and suspended load around 1,275,958.63 m³/year or around 0.581 mm/year. With 6 unit additional Sabo Dam locations (vol: 9,563,750 m³) equipped with groundsill, the estimated useful life of the river will not be disturbed by the sediment for about 7.5 years.

1. Introduction
The problem of sedimentation in the Matakabo river or critical location can be divided into 2 (two) areas that are affected by sedimentation and the areas that are the sources of sedimentation. The affected area is a location that developed to be the productive land or a place where raw water infrastructure is built to utilize water resources that experience the threat of water damage or sediment flow [1-2]. Sediment source areas are prone locations causing sediment flow from soil erosion and erosion of cliffs and river beds. The problems based on their location are described as follows:
Problems with locations affected by sedimentation:
- Decreased function of Matakabo weir,
- Cliff erosion in the upper reaches of Matakabo dam,
- The obstruction of the function of the mud bag drain channel left and right of the Matakabo weir.
- Meanders and shapes of sediments with the deltas due to agitation of river beds,
- Reduced drainage capacity at river troughs,
Based on the existing problems, the construction of the sabo dam is only considered to be a quick solution to the handling of flood problems due to high sedimentation to maintain river water utilization.

2. Materials and methods
The Sabo Dam plan, referring to the Sabo Technology literature published by the Directorate of River and Coast, Ministry of Public Works in 2010 [3-4]. The location selection of Sabo Dam refers to the following theory as can be seen in figure 1.

![Figure 1. Sabo basic point](image)

The point on the river channel that can be considered to be chosen as Sabo Basic Point is:
- a. The point of meeting the river with its branches,
- b. Alluvial fan shape,
- c. Runoff point,
- d. The transition point between debris flow area and sediment flow.

2.1 Design rainfall analysis
Using rainfall station and Amahai 2004 - 2013 to calculate the region's rainfall using the average algebraic method with the following formula [5-6]:

\[
\bar{R} = \frac{R_1 + R_2 + \cdots + R_n}{n} = \frac{\sum_{i=1}^{n} R_i}{n}
\]

where:
\(\bar{R}\) = average rainfall in watershed (mm)
R1, R2, Rn = rainfall in station (mm)
n = number of rainfall station

Design rainfall calculations and Frequency Analysis with EJ Gumbel Type I and Log Pearson Type III Methods. The results of the Frequency Analysis tested with Chi-Square.

2.2. Flood Discharge Design Analysis
2.2.1 HSS Nakayasu Method
The formula of Nakayasu Synthetic unit hydrograph is:

\[
Q_p = \frac{(CA)_R_o}{3.6 \left( 0.3T_p + T_{0.3} \right)}
\]

where:
\(Q_p\) = Peak Flood Discharge (m³/s)
\(R_o\) = Unit Rainfall (mm)
Tp = Interval time from initial rainfall to peak flood (hour)  
T_{0.3} = Time for reduced discharge from peak flood until 30% from peak flood  
C.A = Catchment area to the outlet (km$^2$)

### 2.2.2 HSS ITB 1 Method

The formula from HSS ITB 1 is:

$$Q_p = \frac{R}{3.6T_p} \times \frac{A_{DAS}}{A_{HSS}}$$  \hspace{1cm} (3)

where:
- $Q_p$ = Peak flood discharge (m$^3$/s)
- $R$ = Unit rainfall (mm)
- $T_p$ = Interval time from initial rainfall to peak flood (hour)
- $A_{DAS}$ = Catchment Area (km$^2$)
- $A_{HSS}$ = Catchment of HSS (km$^2$)

### 2.3 Sediment Analysis

#### 2.3.1 Van Rijn Method (suspended load)

The formula of calculation is [5-6]:

$$S_s = F \cdot U \cdot h \cdot C_a \left\{ 0.3 \leq Z \leq 3 \right\} \left( 0.01 \leq \frac{a}{h} \leq 0.1 \right)$$  \hspace{1cm} (4)

where:
- $F = \left( \frac{a}{h} \right)^{1.7} \left( \frac{a}{h} \right)^{1.2} \left( 1 - \frac{a}{h} \right) \left( 1.2 - Z \right)$  \hspace{1cm} (5)

where:
- $Z_0 = 0.033$  \hspace{0.5cm} \text{ks} = \text{thick of Nikuradse rudeness equivalen}$
- $U$ = Average velocity
- $h$ = Flow depth (m)
- $C_a$ = Referention of concentration
- $Z$ = Number of modified suspended = $Z + \phi$

#### 2.3.2 Van Rijn & MPM Method (Bed Load)

The formula of calculation is:

$$G = 1.606 B \times \left[ 3.306 \times \left( \frac{Q_{ba}}{Q} \right) \times \left( \frac{D_{90}}{n_s} \right)^{1/2} \times d \times S - 0.627Dm \right]^{1/2}$$  \hspace{1cm} (6)

where:
- $G$ = Base Load (ton/day)
- $B$ = River wide (m)
- $Q_{ba}$ = Discharge flow on suspended load (m$^3$/s)
- $Q$ = River discharge (m$^3$/s)
- $D_{90}$ = Percentage passing from diameter 90% (mm)
- $n_s$ = Manning coefficient from the river
- $n_m$ = Manning coefficient from the total length of the river
- $n_w$ = Manning Coefficient of river slope
- $Dm$ = Average diameter
- $d$ = Average from a depth of river (m)
- $S$ = River bed slope
2.3.3 Van Rijn and Einstein Method (Bed Load)
The formula of calculation is:

\[ S = \phi (\Delta g D_{35})^{\frac{1}{3}} ; \quad \phi = \frac{P}{A_e - PA_e} \]  

(7)

Where:
- \( S \) = Volume of sediment transport (m\(^3\)/s/m\(^3\))
- \( \phi \) = Constanta = \( f(\psi) \)
- \( D \) = Diameter of sediment
- \( \psi \) = Effective slope
- \( I \) = River bed slope
- \( R \) = Hydraulic radius (m)
- \( A \) = Area of river channel (m\(^2\))

2.4. Design of Sabo Dam
The Matakabo Sabo Dam plan, referring to the Sabo Technology literature published by the Directorate of Rivers and Beaches, Ministry of Public Works in 2010 is outlined with the flow chart as follows can be seen in figure 2.

**Survey Detail:**
Topographic survey scale 1:500 – 1:100 (contour interval 1m)
Cross section survey scale 1:100 – 1:500
Long section survey scale (V) 1:100 – 1:200 and scale (H) 1:500 – 1:1000

**Figure 2.** Sabo dam flow chart design
3. Results and discussion
Sabo Dam placement, in accordance with the guidelines, is described as follows:

**Figure 3.** Sabo dam placement at Matakabo river

**Figure 4.** Sabo dam placement and groundsill at Matakabo river

The result of hydrological calculation. The results of the hydrological analysis as a basic for calculating the Sabo Dam Matakabo design are described as follows:

3.1 Rainfall design
The results of the rainfall calculation where the daily rain is converted into hours are listed as follows:
Table 1. Flood discharge design of Matakabo Sabo dam.

| t Hours | Rt (%) | Netto Rainfall (Rn, mm) with return period (year) |
|---------|--------|-------------------------------------------------|
|         |        | 2   | 5   | 10  | 20  | 25  | 50  | 100 | 200 |
| 1       | 55.032 | 93.69 | 113.54 | 123.23 | 131.10 | 132.73 | 138.34 | 143.0 | 152.45 |
| 2       | 14.304 | 55.03 | 51.56 | 62.49 | 67.82 | 72.14 | 73.04 | 76.13 | 78.70 | 83.89 |
| 3       | 10.034 | 14.30 | 13.40 | 16.24 | 17.63 | 18.75 | 18.99 | 19.79 | 20.46 | 21.81 |
| 4       | 7.988  | 7.98 | 7.48 | 9.07 | 9.84 | 10.47 | 10.60 | 11.05 | 11.42 | 12.18 |
| 5       | 6.746  | 6.74 | 6.32 | 7.66 | 8.31 | 8.84 | 8.95 | 9.33 | 9.65 | 10.28 |
| 6       | 5.896  | 5.89 | 5.52 | 6.69 | 7.27 | 7.73 | 7.83 | 8.16 | 8.43 | 8.99 |

Hourly Netto Rainfall = Rn x Rt

3.1.1 Flood discharge design

The design of flood discharge using $Q_{100}$, where the flood discharge method selected after going through the field calibration process, is the HSS ITB Method. The design flood discharge calculation is listed as follows:

Table 2. Flood discharge design of Matako Sabo dam.

| No. | Name of Sabo Dam | Area (km$^2$) | Q peak ($Q'$) (m$^3$/s) | Sediment Concentration Ratio ($\alpha$) | Q design ($Q = Q' \times (1 + \alpha)$) (m$^3$/s) |
|-----|------------------|---------------|--------------------------|----------------------------------------|--------------------------------------------------|
| 1.  | Wai Sop          | 28.34         | 179.65                   | 10%                                    | 197.62                                           |
| 2.  | Wai Mol          | 28.31         | 159.68                   | 10%                                    | 175.65                                           |
| 3.  | Wai Sol          | 20.42         | 117.81                   | 10%                                    | 129.60                                           |
| 4.  | Wai Bemes        | 18.99         | 113.53                   | 10%                                    | 124.88                                           |
| 5.  | Wai Jana         | 13.28         | 89.18                    | 10%                                    | 98.10                                            |
| 6.  | Wai Ines         | 5.89          | 47.13                    | 10%                                    | 51.84                                            |
| 7.  | Groundsill Matakabo | 166.3       | 585.62                   | 10%                                    | 644.19                                           |

3.1.2 The Result of sediment transport

By using several methods, the calculation of sediment transport is listed as follows:

Table 3. Result of sediment transport.

| No. | Method          | Sediment Transport (S) m$^3$/year | mm/year |
|-----|-----------------|----------------------------------|---------|
| 1   | Van Rijn        | 17.549.400.59                    | 7.9870  |
| 2   | Van Rijn and MPM| 1.275.958.63                     | 0.5807  |
| 3   | Van Rijn and Einstein| 1.178.842.81          | 0.5635  |

Van Rijn dan MPM method was chosen that is equal to $1.275.958.63$ m$^3$/year or around $0.5807$ mm/year

3.1.3 Sabo dam design

Matakabo Sabo dam design has a technical data storage capacity is listed as can be seen in table 4.
Table 4. Matakabo Sabo dam design

| No. | Name of Sabo Dam | i   | Width (m) | High (m) | Length (km) | Volume (m$^3$) |
|-----|-----------------|-----|-----------|----------|-------------|----------------|
| 1   | Wai Sop         | 0.04036 | 50       | 3.50     | 13.83       | 2.420.250     |
| 2   | Wai Mol         | 0.068669 | 50      | 3.50     | 10.99       | 1.923.250     |
| 3   | Wai Sol         | 0.06757  | 50      | 3.50     | 10.06       | 1.760.500     |
| 4   | Wai Bemes       | 0.05745  | 50      | 3.50     | 9.10        | 1.592.500     |
| 5   | Wai Jana        | 0.04939  | 50      | 3.50     | 6.68        | 1.169.000     |
| 6   | Wai Ines        | 0.06384  | 50      | 3.50     | 3.99        | 698.250       |

Total : 9,563,750

Useful Life of Sabo Dam is equal to: 9,563,750 / 1,275,958.63 = 7.49 years

4. Conclusion and recommendation

Conclusion results and recommendations are outlined as follows:

- The sedimentation rate of the Matakabo River based on the Van Rijn and MPM formulas is 1,275,958.63 m$^3$/year while the total storage of 6 Sabo Dam that will be planned is 9,563,750 m$^3$/year.
- With the addition of 6 Sabo Dam, the benefits of the river will be obtained for around 7.5 years.
- The use of water for irrigation and raw water can be optimized if the pattern of operation and maintenance is reliable and supports the maintenance of sabo dam performance.
- Construction Sabo Dam as an effort to control floods will not be effective if it is not parallel with conservation efforts at the upper reaches of the river to reduce the amount of sediment and direct runoff.

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