

Evaluation Lifetime Service and Capacity of the Kadumalik Dam Reservoir

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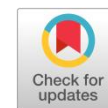
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ABSTRACT

The dam is a construction of water structures built across the river. The function of the dam is to hold and store water, both rain water, river water and water from the lake which will then form a reservoir. Kadumalik Dam is one of the projects of the Directorate General of Water Resources (SDA) of the Ministry of Public Works and Public Housing (PUPR) which will be built in 2020 on an area of 500 Ha. The purpose of building Kadumalik Dam is to meet the irrigation needs of the Irrigation Area (D.I) and meet diverse water needs, but the dam can also pose a great risk as well, namely the risk of accumulation of sedimentation. Sedimentation is one of the factors that is very influential in dam management. A large sedimentation rate will speed up the service life of the reservoir so that the planned reservoir function can be disrupted. Therefore this research is important to know how much the dam capacity and how old the dam service. This study uses analytical calculation methods for sediment transport based on observations and calculation methods with efforts to handle sedimentation. Based on the results of the analysis, the sedimentation rate in the Kadumalik Reservoir is 2.71 tons / ha / year and is classified as an erosion hazard class I or very light erosion rate, calculation of the method with sedimentation handling measures results in the analysis of the Sediment Control Building (BPS) can control 2.2 million m³ of sediment, so that it can extend the reservoir service life to 50 years.



KEYWORDS

Dam
Kadumalik
Sedimentation
Cilutung
Capacity



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1. Introduction

The dam is a construction of water structures built across the river. The function of the dam is to hold and store water, both rain water, river water and water from the lake which will then form a reservoir. Reservoirs can be interpreted as a container or place formed by containment. Reservoirs can play a role in meeting the needs of raw water for drinking water, distribution of irrigation water to paddy fields, hydropower (PLTA), flood control, and tourism [1], [2], [3].

Kadumalik Dam is one of the projects of the Directorate General of Water Resources (SDA) of the Ministry of Public Works and Public Housing (PUPR) which will be built in 2021 on an area of 500 Ha. The purpose of the construction of the Kadumalik Dam is to meet the irrigation needs of the Cilutung Irrigation Area (D.I) and meet diverse needs [4].

Dam construction aims to meet diverse water needs, but dams can also pose a great risk, namely the risk of sedimentation [2]. Sedimentation is one of the factors that is very influential in dam management [2]. A large sedimentation rate will speed up the service life of the reservoir so that the planned reservoir function can be disrupted [2], [3]. This study aims to determine how much capacity and age of dam services by evaluating the rate of sedimentation that occurs in the reservoir with the existing analytical methods of sediment transport, and the method of calculation by handling sedimentation in the Kadumalik Reservoir (DTA) catchment area (Figure 1) [5], [6], [7].

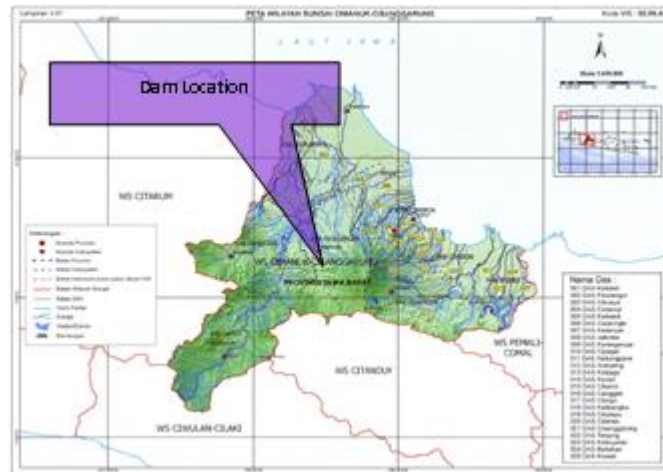


Fig. 1. Location of the Kadumalik Dam

2. Method

The steps taken to predict the sedimentation rate in the Kadumalik Reservoir are as follows [8]:

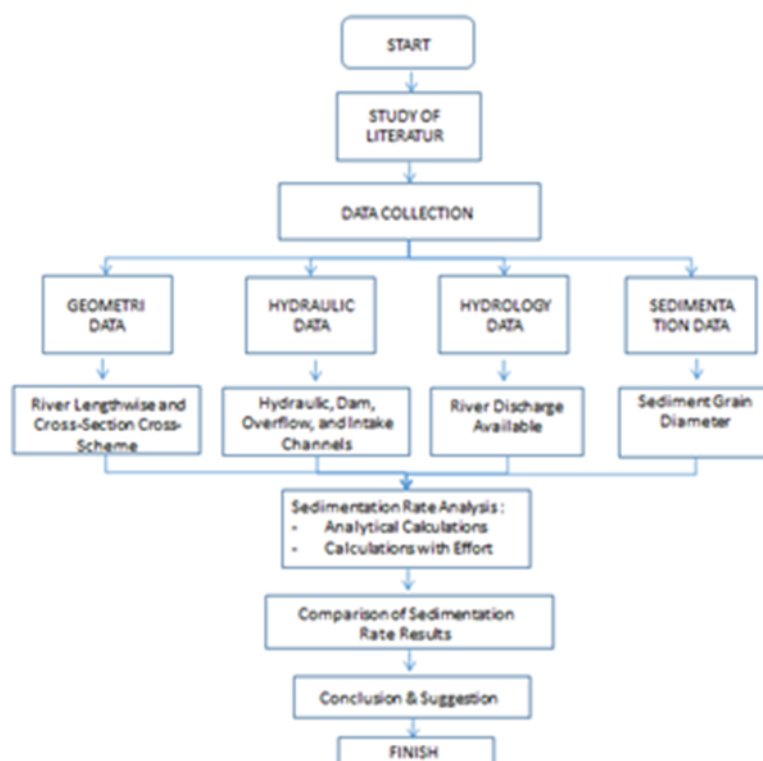


Fig. 2. Flow Diagram of Sedimentation Rate Prediction

3. Results and Discussion

3.1. Sediment Analysis Results

Hydrological processes, directly or indirectly, are associated with erosion, sediment transport and sediment deposition in downstream areas. Changes in land use and watershed management practices also affect erosion, sedimentation, and in turn, will affect water quality [9], [5].

Sedimentation can be known from the amount of erosion in an area. One formula that can be used to predict the amount of erosion is a model developed by Wischmeier and Smith (1978), commonly known as the Universal Soil Loss Equation (USLE). This model is considered the most popular method and is widely used to predict the magnitude of erosion [2], [10], [9], [6].

By using the USLE equation it can be predicted the average rate of erosion of a particular parcel of land, on a steep slope and with certain rainfall patterns, for each type of crop and management measures (soil conservation measures) that are or may be undertaken. The equation used groups various physical (and management) parameters that affect the rate of erosion into six main parameters, with the following equation [2], [10], [9], [6]:

$$A = R \times K \times LS \times CP$$

With,

A = amount of eroded land (tons / ha / year)

R = rain erosivity factor (cm / year)

K = soil erodibility factor

L = slope length factor

S = slope steepness factor

C = factor of land cover vegetation and crop management

P = special soil conservation action factor

With the USLE equation above, and by obtaining factor values from the erosion parameters then the amount of land erosion can be calculated [2], [10], [9], [6], [7]. To find out the level of erosion hazard in certain areas can be seen based on the erosion hazard class qualifications as presented in Table 1.

R: 5.71

K: 0.47

LS : 3.10

CP: 0.33

So,

$A = R \times K \times LS \times CP$

$= 5.71 \times 0.47 \times 3.10 \times 0.33$

$= 2.71 \text{ ton/ha/tahun}$

With the value of A = 2.71 tons / ha / yr according to the table below, the Kadumalik reservoir area is classified into the erosion hazard class I (very light) [2], [10], [4], [7].

Table 1. Table 1 Erosion Danger Class Classification

Erosion Danger Class	Land lost, A, in [tons / ha / year]	Remarks
I	< 15	Very Light
II	15 - 60	Light
III	60 - 180	Medium
IV	180 - 480	Heavy
V	> 480	Very Heavy

The sediment transport rate in the river consists of two parts, namely suspension sediment transport and elevated sediment transport. For the calculation of the elevated sediment rate can be calculated by multiplying the sediment concentration with the average river discharge, while for the basic sediment transport it can be calculated by the MPM and Einstein equations [2], [10], [7], [8], [11].

The equation for calculating elevated sediment is given as follows:

$$Q_s = 0,0864 \times C \times Q_w$$

Note :

Q_s = overflow sediment discharge (ton/day)

C = sediment concentration (gr/lt)

Q_w = river water discharge (m³/s)

As for the MPM equation, given as follows:

$$G = 1,606 B \times (3,306 \times (Q_B/Q) (D_{90}^{1/6} / n_s)^{3/2} \times d \times S - 0,627 D_m)^{3/2}$$

Note:

G = bed load (ton/day)

B = river width (m)

Q_B = river discharge on bed load (m³/s)

$$= Q / (1 + 2d/B \times (1 - (n_w/n_m)^{3/2}))$$

Q = total discharge (m³/s)

D_{90} = diameter with 90% escaped granules

n_s = manning coef at the bottom of the river

$$= n_m \times (1 + 2d/B \times (1 - (n_w/n_m)^{3/2}))$$

n_m = manning coef at all parts of the river

n_w = manning coef on riverbanks

D_m = active diameter / average diameter

d = average water depth (m)

S = slope

And Einstein equation given bellow:

$$G = 43,2 \times B \times ((1/(*D_i)^{0,5}) \times 437,9 \times S / 2 \times (q - q_{oi}))$$

Note :

G = Bed load transportation (ton/day)

B = River width (m)

D_i = Geometric mean dimaters of individual sample fractions(mm)

S = Slope

q = Discharge per unit width

$$q_{oi} = 0,00021 \times D_i / S^{4/3}$$

Based on calculations using the MPM method, the sediment transport rate at the Kadumalik Dam planned location is 2.38 million m³ / year or 6.11 mm / year. As for the Einstein method, a sediment transport rate of 2.61 million m³ / year or 6.72 mm / year was obtained. In subsequent calculations, the results of the Einstein method are used [2], [10], [4].

To calculate the amount of sediment trapped in a reservoir, the following equation is used:

$$DEAD_t = DEAD_{t-1} + (TE_t \times SL \times A)$$

Where:

DEADt = volume of dead reservoir in the t-year

TEt = efficiency trap

SL = sedimentation rate (m / year)

A = catchment area (m²)

Based on the results of sedimentation analysis, it appears that sedimentation will reach intake elevation between the 9th and 10th years. Calculation results can be seen in Table 2. [12], [4].

Table 2. Kadumalik Reservoir Sedimentation Calculation

Year to	Capacity (mcm)	(C/lw)	log (C/lw)	TE	Sediment Vol. (m ³)	Cum. Sed. Vol. (m ³)	Cum. Sed. Vol. (mcm)	Sediment Elev. (m)
1	47,50	0,069	-1,161	0,780	2.040.287,14	2.040.287,14	2,0403	196,95
2	45,46	0,066	-1,180	0,775	2.026.234,65	4.066.521,79	4,0665	208,77
3	43,43	0,063	-1,201	0,769	2.011.388,21	6.077.910,00	6,0779	215,98
4	41,42	0,06	-1,222	0,763	1.995.674,29	8.073.584,29	8,0736	221,23
5	39,43	0,057	-1,244	0,757	1.979.009,76	10.052.594,05	10,0526	225,36
6	37,45	0,054	-1,268	0,750	1.961.300,26	12.013.894,31	12,0139	228,78
7	35,49	0,051	-1,292	0,743	1.942.438,15	13.956.332,46	13,9563	231,7
8	33,54	0,048	-1,319	0,735	1.922.300,19	15.878.632,65	15,8786	234,24
9	31,62	0,046	-1,337	0,727	1.900.744,51	17.779.377,16	17,7794	236,49
10	29,72	0,043	-1,367	0,718	1.877.607,03	19.656.984,19	19,6570	238,50

Based on the results of the analysis in Table 2, it can be seen that the service life of the dam only reaches the age of 10 years, this shows that the service life of the Kadumalik Reservoir is very short. Therefore, efforts should be made to handle sedimentation in the Kadumalik Reservoir catchment area. One of the efforts to handle this can be done by building a BPS (Sediment Control Building). The results of the sedimentation calculations with the efforts are listed in Table 3 [4].

Table 3. Kadumalik Reservoir Sedimentation Calculation (With Efforts)

Year to	Capacity (mcm)	(C/lw)	log (C/lw)	TE	Sediment Vol. (m ³)	Cum. Sed. Vol. (m ³)	Cum. Sed. Vol. (mcm)	Sediment Elev. (m)
10	46,05	0,07	-1,177	0,777	321.609,96	3.216.100	3,2161	191,79
20	42,85	0,06	-1,208	0,768	318.892,93	6.405.029	6,4050	212,05
30	39,69	0,06	-1,242	0,758	313.824,60	9.543.275	9,5432	221,26
40	36,57	0,05	-1,277	0,747	309.349,56	12.636.771	12,6367	205,13
50	33,50	0,05	-1,316	0,735	304.399,86	15.680.769	15,6808	232,15

Based on the calculations listed in Table 3, assuming that BPS can control 2.2 million m³ of sediment, 50 years of service life of the Kadumalik Reservoir can be achieved [4].

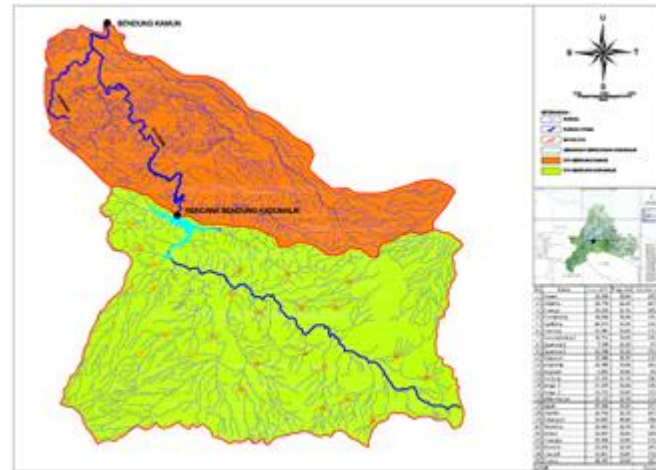


Fig. 3.Sediment Control Building Potential Locations

3.2. Potential Deposits

The location of the dam in the watershed, is determined based on the comparison of the volume of reservoirs in 2 alternative dam locations. The potential of the reservoir is calculated based on a topographic map by first calculating the area of each contour line of the reservoir. This area was calculated with the help of CAD software. The storage volume is calculated using the truncated cone formula for inundation pits between two contour planes [12], [4], [13], [14], [7], [8], [11].

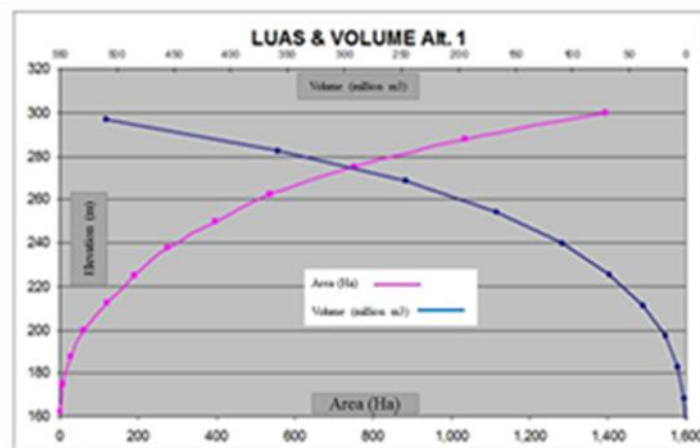


Fig. 4.Curved Area and Volume of Reservoir Locations (1)

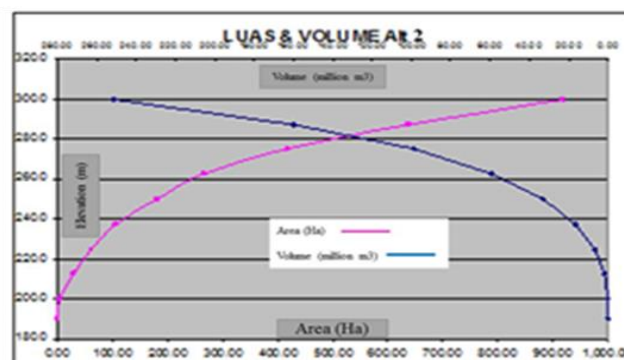


Fig. 5.Curved Area and Volume of Reservoir Locations (2)

Based on the graph above it can be concluded that from the two locations with the same elevation difference, the maximum reservoir storage capacity volume is located at the 1st Location [4]. With the following explanation :

- 1st Alternative Basin, up to +300 m elevation, can accommodate a volume of 509.77 million m³, and has a pool area of 1392.80 Ha.
- 2nd Alternative Basin, up to +300 m elevation, can accommodate a volume of 268.46 million m³, and has a pool area of 919.95 Ha.

4. Conclusion

Some things that can be concluded from this study are as follows [4], [13], [14], [7], [8], [11]:

- a. The potential volume of the Kadumalik Reservoir reservoir is 509.77 million m³ at an elevation of 300 m and has a pool area of 1392.80 Ha, which is found in 1st alternative.
- b. The Sediment Control Building (BPS) can control 2.2 million m³ of sediment, thus extending the reservoir service life by 50 years.
- c. The sedimentation rate in the Kadumalik Reservoir is 2.71 tons / ha / year and is classified as an erosion hazard class I or very mild erosion rate

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Hopefully this research can be useful for us and especially for civil engineering practitioners in the field of water construction.

References

- [1] A. J. Peterka, *Hydraulic design of stilling basins and energy dissipators*. Citeseer, 1974. Available at [Google Scholar](#)
- [2] S. Sosrodarsono and K. Takeda, *Bendungan Type Urugan*. PT Pradnya Paramita, Jakarta, 1977. Available at [Google Scholar](#)
- [3] S. Sudirman *et al.*, *Sistem Irigasi dan Bangunan Air*. Yayasan Kita Menulis, 2021. Available at [Google Scholar](#)
- [4] U. S. Sanutri, Y. Suharnoto, A. Sapei, and C. Suhendi, "Hydrological Analysis of Kadumalik Reservoir Design To Fulfill Water Demands of the Plan In the Cilutung IA (Irrigation Area)," in *2020 6th International Conference on Computing Engineering and Design (ICCED)*, 2020, pp. 1–6. Available at [Google Scholar](#)
- [5] V. T. Chow, D. R. Maidment, and L. W. Mays, "Applied hydrology McGraw-Hill International editions," *New York, USA*, 1988. Available at [Google Scholar](#)
- [6] I. Latifah, "Analisis ketersediaan air, sedimentasi, dan karbon organik dengan model SWAT di Hulu DAS Jeneberang, Sulawesi Selatan [Tesis]," *IPB. Bogor*, 2013. Available at [Google Scholar](#)
- [7] F. A. R. Shiami, "Prediksi Laju Sedimentasi pada Tampungan Bendungan Tugu Trenggalek." Institut Teknologi Sepuluh Nopember, 2017. Available at [Google Scholar](#)
- [8] S. Andrey and R. P. Thomas, "PERENCANAAN BANGUNAN PENGENDALI SEDIMEN DI KALI KREO." Diponegoro University, 2014. Available at [Google Scholar](#)

- [9] C. Asdak, *Hidrologi dan pengelolaan daerah aliran sungai*. Gadjah Mada University Press, 2018. Available at [Google Scholar](#)
- [10] B. Triatmodjo, "Hidrologi Terapan. Yogyakarta: Beta Offset. 355 hlm," *Nurjaya IW, Surbakti H*, pp. 140–150, 2009. Available at [Google Scholar](#)
- [11] A. Bagiawan, "Perhitungan Kebutuhan Kapasitas Tampung bagi Rencana Pengembangan Areal Layanan Irigasi dari Bendung Perjaya–Sumatera Selatan dengan Metode Numerik dan 'Sequent Peak,'" *J. Irig.*, vol. 8, no. 1, pp. 1–14, 2013. Available at [Google Scholar](#)
- [12] B. Meteorologi, "Klimatologi, dan Geofisika. 2017," *Curah Hujan Padang Mengatas. sumber data Badan Meteorologi, Klimatologi, dan Geofis. Stasiun Klimatologi Sicincin. Sumatera Barat (ID).*[Tidak di Publ., 2013. Available at [Google Scholar](#)
- [13] M. Imamuddin, "Evaluasi Kapasitas Tampungan Setu Tarisi Kabupaten Majalengka," *Pros. Semnastek*, 2016. Available at [Google Scholar](#)
- [14] D. Anggraheni, R. Jayadi, and I. Istiarto, "EVALUASI KINERJA POLA OPERASI WADUK (POW) WONOGIRI 2014," *Teknisia*, vol. 22, no. 1, pp. 294–306, 2017. Available at [Google Scholar](#)