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TEKNIK, 46 (2), 2025, 162-170

Analysis of Changes in Sedimentation Volume of Kuwil Kawangkoan Reservoir with USLE Method and Area Reduction Method

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Abstract

Sediment deposited in the reservoir will increase in line with the total erosion rate. This causes the dead storage capacity of the reservoir to siltation, so studies need to be performed to estimate the amount of erosion rate and sediment distribution during the reservoir's operational period. The study location is at the Kuwil Kawangkoan Reservoir, North Minahasa Regency, North Sulawesi Province. The study aims to determine the reservoir erosion rate using the USLE Method based on Geographic Information Systems (GIS) and to analyze changes in the reservoir sedimentation storage volume using the Area Reduction Method. Based on the analysis, the volume of sediment deposited in the Kuwil Kawangkoan Reservoir catchment area is 307,382.08 m^3/tahun. Over a 50-year lifespan, the predicted total volume of settled sediment is 15.369 million m^3. The results of the sediment distribution analysis indicate that after 50 years, only 17.82% of the dead storage capacity will remain. Initially, the dead storage capacity of the reservoir was 7.63 million m^3, but it is projected to decrease to 1.36 million m^3 at an elevation of +77.00 m, below the intake elevation. Since the intake elevation of the Kuwil Kawangkoan Reservoir is at +83.50 m, the operation of Kuwil Kawangkoan Reservoir to fulfil water demand downstream is relatively unaffected.

Keywords*: Area Reduction, Erosion, Kuwil Kawangkoan Reservoir, USLE*

1. Introduction

The Kuwil Kawangkoan Reservoir is a national strategic project (PSN) that confers several benefits to Manado City. Chief among these is its use as a flood control measure, as well as its role in supplying 4.50 m^3/dt of raw water to the city's residents. The reservoir's inundation area encompasses 157 hectares, with a flood storage volume of 5.94 million cubic meters, an effective storage capacity of 19.26 million cubic meters, and a dead storage capacity of 7.63 million cubic meters.

The issue of sedimentation is a common challenge in reservoir management. Globally, sedimentation in reservoirs continues to increase, with storage capacity estimated to decline from 16% in 2022 to 26% by 2050 (Perera et al., 2023). This issue also affects reservoirs in various regions, including Indonesia, a tropical country with a high erosion rate. Land erosion in reservoir catchment areas is the primary cause of sedimentation, with natural erosion rates of 2–3 tons/ha/year. In contrast, cultivated land can experience erosion rates of 40–400 tons/ha/year, while deforested land exhibits even more extreme erosion rates, reaching 120–460 tons/ha/year (Nugroho & Dibyosaputro, 2015).

Inappropriate land use in the catchment area (DTA) can lead to increased sediment accumulation at the bottom of the reservoir (Juldah et al., 2023). This sediment accumulation not only reduces reservoir storage capacity but also affects reservoir stability and safety (Krisnayanti et al., 2018). Several studies indicate that 70% of reservoirs face the same issue, namely sediment deposition at the reservoir bed, which prevents the operational service life of the reservoir from being achieved as planned (Asrib, 2012). The operational service life of a reservoir is determined by calculating the time required for the dead storage capacity to be completely filled with sediment (Mukti, 2019). Based on these issues, a study on sedimentation rate prediction and sediment distribution in the Kuwil Kawangkoan Reservoir is needed to ensure the sustainability of its functions.

The sedimentation rate prediction utilizes the Universal Soil Loss Equation (USLE) method integrated with Geographic Information Systems (GIS). The USLE method is advantageous as it is suitable for tropical regions and requires fewer parameters compared to more complex methods, such as the Griffith University Erosion System Template (GUEST) and the Agricultural Non-Point Source Pollution Model (AGNPS) (Seran, 2022). Meanwhile, the sediment distribution in the Kuwil Kawangkoan Reservoir is analyzed using the Area

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doi: 10.14710/teknik.v46i2.65307

Reduction Method, as this approach is considered to have lower uncertainty compared to the Area Increment Method (Tukaram et al., 2016).

The purpose of this study is to determine the level of erosion in the Kuwil Kawangkoan Reservoir and to determine changes in the reservoir sedimentation storage volume. The results of this study are expected to be useful to the Kuwil Kawangkoan Dam Management Unit as a reference for planning and managing reservoir sedimentation.

2. Materials and Methods

2.1. Study Location

The Kuwil Kawangkoan Reservoir is located downstream of the Tondano River, Kuwil Village, Kalawat District, North Minahasa Regency, which can be seen in Figure 1.

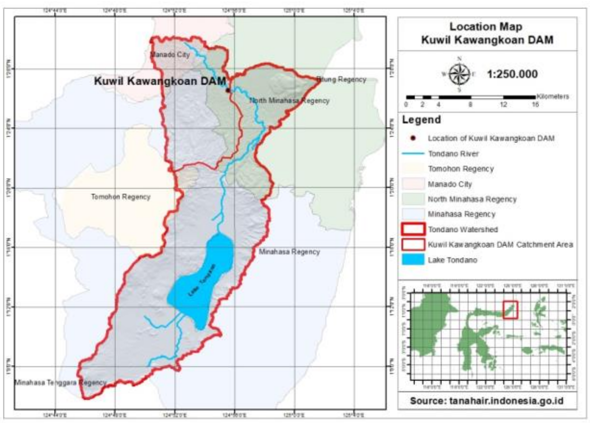

Figure 1. Location of Kuwil Kawangkoan Reservoir

2.2. Data Required

This study requires some secondary data. Such as reservoir capacity curve data and rainfall data at the closest station to the DTA of the Kuwil Kawangkoan Reservoir obtained from BWS Sulawesi I, land use data obtained from the Geospatial Information Agency, soil type data obtained from the FAO Digital Soil Map of the World (DSMW), and topographic data obtained from the Geospatial Information Agency to create watershed boundaries and determine the slope.

2.3. Research Process

Predict the Erosion Rate

The erosion rate value at the Kuwil Kawangkoan Reservoir catchment is estimated using the USLE method formulated in equation 1 (Asdak, 2022):

$$A = R\ K\ LS\ C\ P \quad (1)$$

where A is the amount of soil loss (ton/ha/year), R is the rainfall erosivity factor (KJ/ha/year), K is the soil erodibility factor (ton/KJ), LS is the slope length and steepness factor, C is the land cover factor, and P is the soil conservation or prevention practices factor.

Rainfall erosivity factor formulated in equation 2 (Asdak, 2022):

$$R = 6.12\ (RAIN)^{1.21}\ (DAYS)^{-0.47}\ (MAXP)^{0.53} \quad (2)$$

where R is the erosivity index of the monthly rainfall (KJ/ha/month), RAIN is monthly rainfall (cm), DAYS is the average number of rainy days per month (days), and MAXP is the maximum rainfall within 24 hours (cm).

Potential Sediment

After the erosion rate is obtained, the next step is to calculate the sediment delivery ratio, which is formulated in Equation 3 (Vanoni, 1975):

$$SDR = 0.42\ A^{-0.125} \quad (3)$$

where SDR is a measure of *sediment delivery ratio*, and A is the watershed area (km^2).

Sediment Distribution

Determining the type of reservoir curve is influenced by the reservoir shape, operational system, and sediment particle size. Errors in selecting the curve type may lead to inaccuracies in determining the new zero elevation.

The reservoir shape is defined as the relationship between depth and reservoir capacity, as specified in Table 1. Meanwhile, the reservoir operational system is determined based on Table 2.

Table 1. Curve type based on reservoir shape (Morris & Fan, 1998)

Reservoir Shape	Type	m
Lake	I	3.5 – 4.5
Floodplain-foothill	II	2.5 – 3.5
Hill and gorge	III	1.5 – 2.5
Gorge	IV	1.0 – 1.5

Table 2. Curve type based on reservoir operation (Morris & Fan, 1998)

Reservoir Operation	Operational class	Shape class	Weighted class
Sediment submerged (continuous high pool level)	I	I	I
		II	I or II
		III	II
Moderate drawdown	II	I	I or II
		II	II
		III	II or III
Considerable drawdown	III	I	II
		II	II or III
		III	III
Normally empty	IV		IV

doi: 10.14710/teknik.v46i2.65307

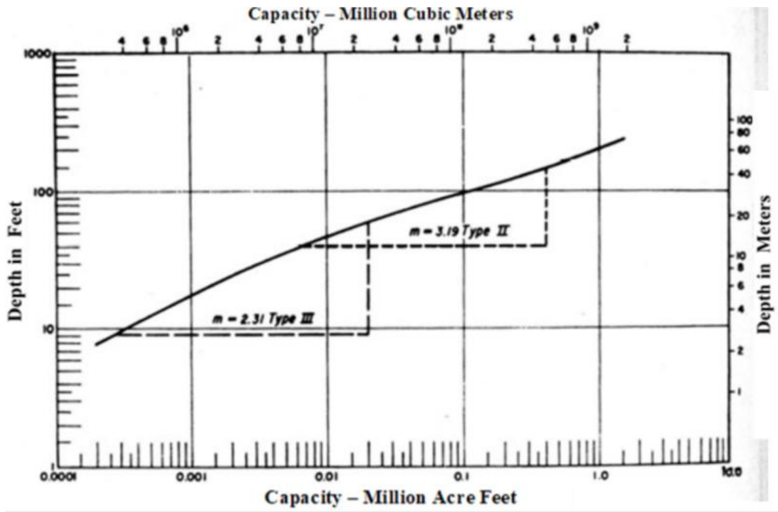

Figure 2. Reservoir capacity and depth relationship graph (Morris & Fan, 1998)

As illustrated in Figure 2, the slope m is derived from the relationship between depth and reservoir capacity, which is plotted on logarithmic paper. In cases where m values vary, the most dominant value can be selected.

The dimensionless value (F) is calculated at each reservoir elevation to determine the new zero depth, according to Equation 4 (Morris & Fan, 1998):

$$F = \frac{S - V_h}{H.A_h} \quad (4)$$

where S is the total deposited sediment (m^3), H is the initial reservoir depth (m), V_h is the reservoir capacity at each depth h (m^3), and A_h is the reservoir surface area at each depth h (m^2). Meanwhile, the relative depth (p) is calculated using Equation 5 (Morris & Fan, 1998):

$$p = \frac{h}{H} \quad (5)$$

where h is the depth at each reservoir elevation (m), and H is the initial reservoir depth (m).

The values of F and p are then plotted in a graph presented in Figure 3. The intersection point with the reservoir curve serves as a reference for determining the new zero elevation of the reservoir.

Based on the new zero depth value, the relative area is then calculated according to the curve type using the following equations (Morris & Fan, 1998):

Type I $\quad a = 5.047 \times p^{1.85} \times (1-p)^{0.36} \quad (6)$
Type II $\quad a = 2.487 \times p^{0.57} \times (1-p)^{0.41} \quad (7)$
Type III $\quad a = 16.96 \times p^{1.15} \times (1-p)^{2.32} \quad (8)$
Type IV $\quad a = 1.486 \times p^{-0.25} \times (1-p)^{1.34} \quad (9)$

where a is the relative area, and p is the reservoir depth at a specific elevation.

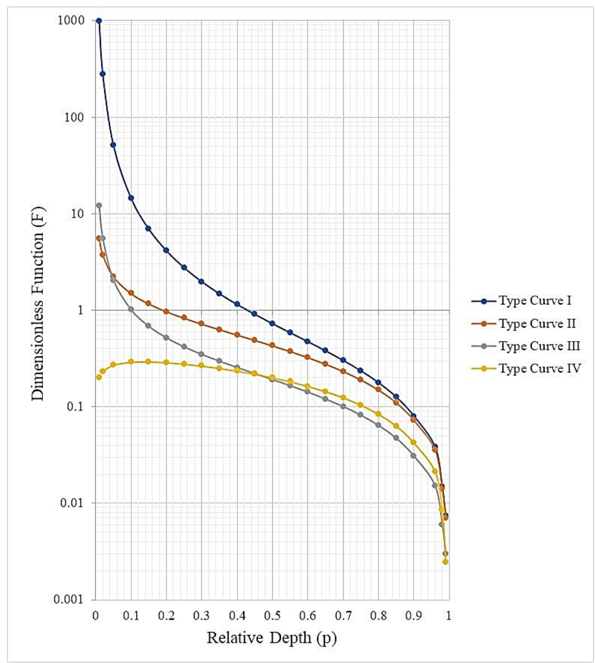

Figure 3. Reservoir Curve Type (Morris & Fan, 1998)

The distributed area is calculated by multiplying the corrected area by the relative area. Next, the additional volume is obtained by multiplying the average distributed area by the depth difference. After that, the cumulative sediment distribution volume is determined by subtracting the additional volume from the total deposited sediment.

The reservoir storage volume after T years is calculated by subtracting the initial reservoir storage capacity from the cumulative storage at each elevation depth.

To help readers better understand the research stages, a flowchart is presented in Figure 4.

doi: 10.14710/teknik.v46i2.65307

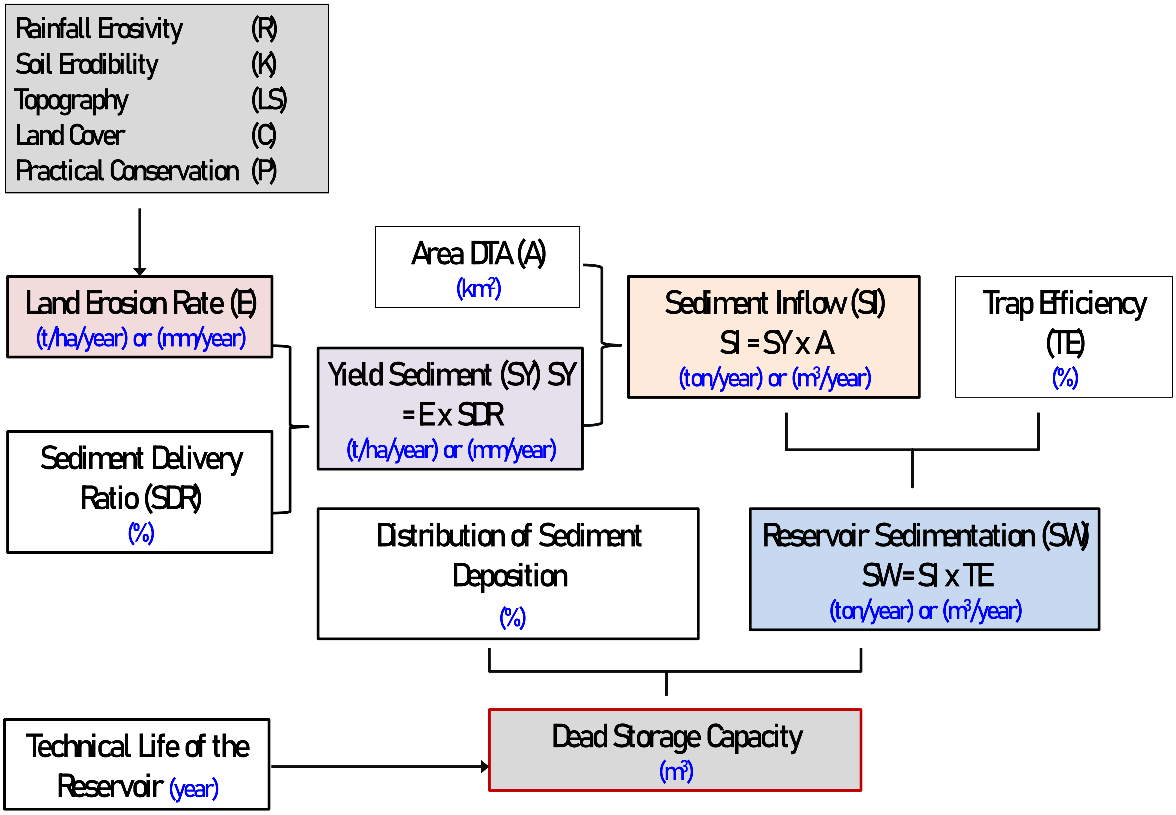

Figure 4. Research Flowchart Diagram

3. Results and Discussion

3.1. Erosion Rate Analysis of Kuwil Kawangkoan Reservoir

Rainfall Erosivity (R)

The analysis of rainfall erosivity is conducted using rainfall data from the stations closest to the Kuwil Kawangkoan Reservoir Catchment Area (DTA), namely Kaelosan, Rumengkor, Kakaskasen, and Winebetan Rainfall Stations, as shown in Figure 5.

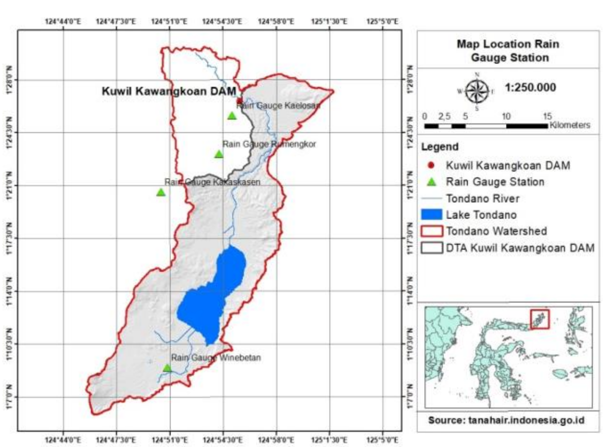

Figure 5. Map of Rain Gauge Station in the Kuwil Kawangkoan Reservoir Catchment Area

The rainfall erosivity value (R) is calculated using Equation 2. The results of this calculation can be seen in Table 3.

Table 3. Erosivity Value (R) of the Kuwil Kawangkoan Reservoir

Month	RAIN (cm)	DAYS (hari)	Max P (cm)	EI30 (KJ/ha/month)
Jan	23.52	18	5.43	171.65
Feb	21.99	20	3.99	129.74
Mar	26.55	19	5.40	195.59
Apr	27.22	16	5.50	219.50
May	22.02	14	4.76	170.16
Jun	12.61	10	2.88	76.19
Jul	14.96	13	3.84	96.89
Aug	19.88	17	5.98	152.26
Sep	18.84	15	4.55	132.50
Oct	22.91	14	4.92	176.89
Nov	27.73	20	4.59	182.39
Dec	21.23	16	6.66	179.37
Amount (KJ/ha/years)				1,883.15

Soil Erodibility (K)

In the DTA Kuwil Kawangkoan Reservoir, there are three types of soil: Vitric Andosols, Eutric Cambisols, and Humic, as shown in Figure 6.

doi: 10.14710/teknik.v46i2.65307

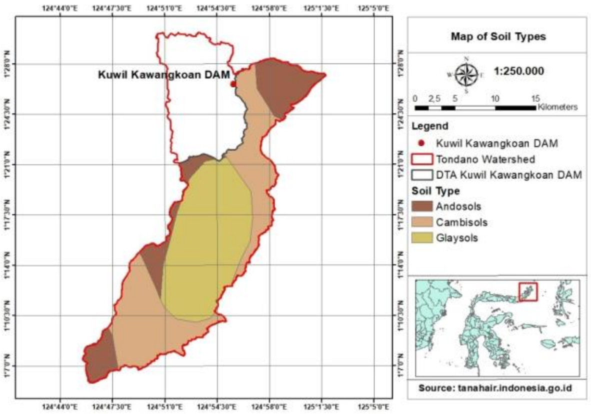

Figure 6. Soil Type of Kuwil Kawangkoan Reservoir Catchment Area

Figure 6 presents the soil erodibility values (K) for each type, which are 0.15, 0.20, and 0.13, respectively (Akplo et al., 2020; Mamo et al., 2019). Based on the analysis, the weighted K value was obtained, as shown in Table 4.

Table 4. Soil Erodibility Value (K) of the Kuwil Kawangkoan Reservoir

Soil Type	Area (Ha)	K	K x Area	Weighted K
Vitric Andosols	8,036.50	0.15	1,205.48	
Eutric Cambisols	16,294.46	0.20	3,258.62	0.162
Humic Glaysols	16,508.90	0.13	2,146.16	
Amount	40,838.49		6,610.25	

Slope Lenght (LS)

The slope factor (LS) depends on the slope class, as shown in Figure 7 (Kironoto & Yulistiyanto, 2000).

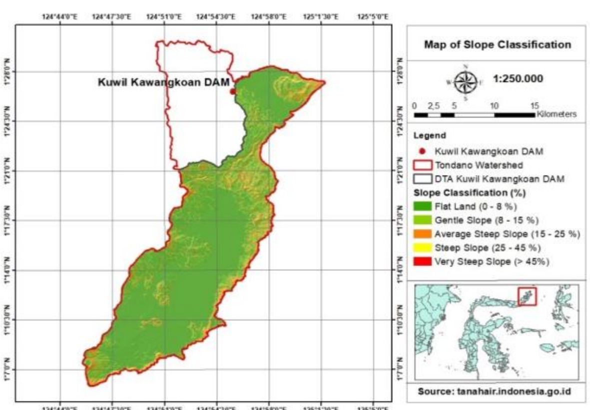

Figure 7. Slope class (LS) of Kuwil Kawangkoan Reservoir Catchment Area

Figure 7 indicates that the slope in the reservoir catchment area (DTA) ranges from flat to very steep. The analysis results provide the weighted LS value, as presented in Table 5.

Table 5. Weighted LS value of Kuwil Kawangkoan Reservoir

No	Slope (%)	Area (Ha)	LS	LS x Area	Weighted LS
1	0 – 8	29,273.26	0.4	11,710.10	
2	8 – 15	7,876.27	1.4	11,026.78	
3	15 - 25	3,212.38	3.1	9,958.36	0.88
4	25 – 45	462.78	6.8	3,146.89	
5	> 45	10.44	9.5	99.17	
	Amount	40,838.49		35,941.30	

Land Cover and Conservation Prevention (CP)

The land cover in the Kuwil Kawangkoan Reservoir Catchment Area (DTA) is dominated by plantations, followed by shrubs, as shown in Figure 8.

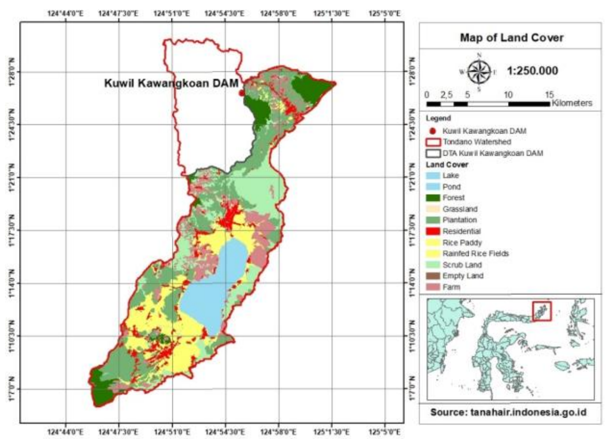

Figure 8. Land Cover of Kuwil Kawangkoan Reservoir Catchment Area

Figure 8 presents the CP factor, which depends on land use type. For example, plantations have a CP value of 0.3 (Suripin, 2004). The analysis results provide the weighted CP value, as shown in Table 6.

Table 6. CP value of Kuwil Kawangkoan Reservoir

Land Cover	Area (Ha)	CP	CP x Area	Weighted CP
Lake	4,551.7	0.001	4.55	
Pond	58.10	0.001	0.06	
Forest	3,164.3	0.001	3.16	
Grassland	53.19	0.01	0.53	
Plantation	10,552.1	0.3	3,165.6	
Residential	2,582.8	1.0	2,582.8	0.197
Rice paddy	7,300.7	0.02	146.01	
Rainfed Rice Fields	3.28	0.05	0.16	
Scrub Land	7,384.5	0.1	738.45	
Empty Land	206.65	0.02	4.13	
Farm	4,901.03	0.28	1,372.2	
Amount	40,838.4		8,017.8	

After obtaining the values of R, K, LS, and CP, the erosion rate is calculated using Equation 1. The results are presented in Table 7.

doi: 10.14710/teknik.v46i2.65307

Table 7. Actual Erosion of the Kuwil Kawangkoan Reservoir Catchment Area

R (KJ/Ha/Years)	K	LS	C	P	Ea (Ton/Ha/Years)
1,883.15	0.16	0.88	0.197	1.0	52.77

Based on Table 7, the erosion rate in the Kuwil Kawangkoan Reservoir Catchment Area (DTA) is 52.77 tons/ha/year. With a total area of 40,838.49 ha, the total erosion amounts to 2,155,164.67 tons/year.

3.2. Potential Reservoir Sedimentation

Sediment delivery ratio (SDR)

The erosion rate in the Kuwil Kawangkoan Reservoir must be multiplied by the Sediment Delivery Ratio (SDR), which represents the proportion of sediment transported from the hillside to the water body (Xu et al., 2024). From equation 3, the SDR value is 0,198. By multiplying the SDR by the erosion rate, the sediment entering the reservoir is calculated to be 426,919.55 tons/year or 512,303.46 m³/year, assuming a soil bulk density of 1.2 tons/m³. The calculation results are presented in Table 8.

Table 8. Yield Sediment (SY) of the Kuwil Kawangkoan Reservoir Catchment Area

Area DTA (km^2)	Ea (Ton/Thn)	SDR	SY (Ton/Thn)	SY (m^3/Thn)
408.38	2,155,164.6	0.198	426,919.5	512,303.4

Trap Efficiency

The yield sediment results obtained must be multiplied by the trap efficiency value using the reservoir capacity-to-inflow (C/I) ratio value and plotted on the Brune graph shown in Figure 9.

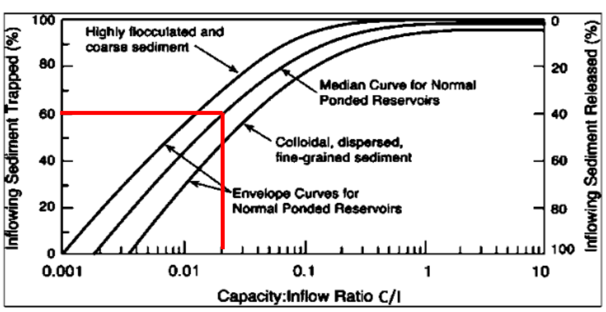

Figure 9. Value of trap efficiency (Brune, 1953)

Figure 9 indicates a trap efficiency of 60 %, derived from a capacity-to-inflow (C/I) ratio of 0.0217. After applying the trap efficiency, the potential sediment deposition in the reservoir reaches 307,382.08 m³/year. Over the 50-year lifespan of the Kuwil Kawangkoan Reservoir, the total accumulated sediment is estimated at 15.369 million m³. This analysis shows an increase in potential sedimentation compared to the 2012 detailed design analysis of the reservoir. The difference is attributed to variations in USLE parameters and the use of more recent data.

3.3. Sediment Distribution Analysis

Before calculating sediment distribution, it is necessary first to determine the type of reservoir curve to distribute sediment. The curve type depends on the shape of the reservoir, the reservoir operating system, or sediment grain size, with the results shown in Table 9.

Table 9. Curve Type of Kuwil Kawangkoan Reservoir

Description	Curve	Information
Reservoir shape	II	Floodplain-foothill
Reservoir operation	II	Moderate drawdown
Sediment grain size	I and II	Silt sand
The curve used	**II**	

Sediment grain size is used as an auxiliary variable to weight the choice of curve type when there is a choice between two curve types (Morris & Fan, 1998). From these three parameters, the Kuwil Kawangkoan reservoir is included in curve type II.

The dimensionless value (F) is calculated at each reservoir depth using Equation (4), and the relative depth (p) is determined using Equation (5). The F and p values are then plotted on a graph, as shown in Figure 10.

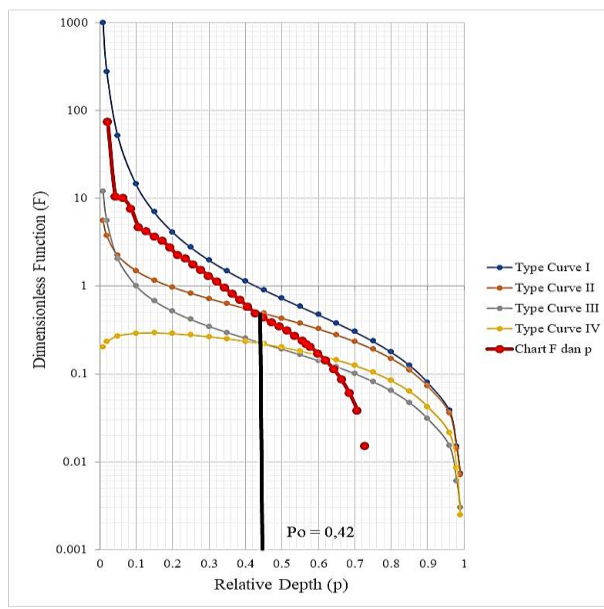

Figure 10. Find Po through the relationship F and p

Figure 10 shows a Po value of 0.42, obtained by plotting the F and p values from Equations (4) and (5), which intersect the type II curve. Using equation (7), the new zero depth of the reservoir is determined to be 20 meters, corresponding to an elevation of +77.00 m. The sediment distribution for each elevation is presented in Table 10.

doi: 10.14710/teknik.v46i2.65307

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Table 10. Sediment Distribution of Kuwil Kawangkoan Reservoir After 50 Years of Operation

Intial Operation (T_0)				F	Relative			Sediment Distribution		50 Year (T_{50})		
Elevation	**Depth (H)**	**Area (Ah)**	**Reservoir Volume (Vh)**		**Relative Depth (p)**	**Relative Area (a)**	**Distributed Area**	**Reservoir Volume Increase**	**Cumulative Volume**	**Area**	**Volume**	
m	**m**	**million m^2**	**million m^3**		**(h/Htot)**	**million m^2**	**million m^2**	**million m^3**	**million m^3**	**million m^2**	**million m^3**	
103.7	46.70	1.81	32.83	-0.207	1.000	0.000	0.000	0.066	15.369	1.807	17.464	*Flood Storage*
103	46.00	1.76	31.58	-0.197	0.985	0.441	0.189	0.228	15.303	1.575	16.273	
102	45.00	1.70	29.84	-0.182	0.964	0.626	0.268	0.294	15.075	1.435	14.768	
101	44.00	1.64	28.17	-0.167	0.942	0.747	0.320	0.340	14.781	1.323	13.390	
100	43.00	1.55	26.57	-0.154	0.921	0.839	0.359	0.375	14.441	1.196	12.131	*Effective storage*
99	42.00	1.53	25.03	-0.136	0.899	0.913	0.391	0.404	14.066	1.134	10.966	
98	41.00	1.47	23.54	-0.119	0.878	0.975	0.417	0.429	13.662	1.050	9.874	
97	40.00	1.41	22.10	-0.102	0.857	1.027	0.440	0.449	13.233	0.972	8.863	
96	39.00	1.36	20.71	-0.084	0.835	1.072	0.459	0.467	12.784	0.897	7.928	
95	38.00	1.30	19.38	-0.066	0.814	1.110	0.475	0.482	12.317	0.827	7.066	
94	37.00	1.25	18.11	-0.047	0.792	1.143	0.490	0.496	11.835	0.759	6.273	
93	36.00	1.20	16.89	-0.027	0.771	1.172	0.502	0.507	11.339	0.694	5.547	
92	35.00	1.14	15.72	-0.006	0.749	1.196	0.512	0.517	10.832	0.633	4.883	
91	34.00	1.09	14.60	0.015	0.728	1.217	0.521	0.525	10.316	0.573	4.280	
90	33.00	1.04	13.53	0.038	0.707	1.234	0.528	0.531	9.791	0.517	3.735	
89	32.00	1.03	12.49	0.060	0.685	1.248	0.534	0.537	9.259	0.491	3.231	
88	31.00	0.97	11.49	0.086	0.664	1.259	0.539	0.541	8.723	0.431	2.770	
87	30.00	0.92	10.55	0.112	0.642	1.268	0.543	0.544	8.182	0.375	2.367	
86	29.00	0.87	9.66	0.141	0.621	1.273	0.545	0.546	7.638	0.323	2.017	
85	28.00	0.82	8.81	0.171	0.600	1.277	0.547	0.547	7.092	0.275	1.718	
84	27.00	0.78	8.01	0.203	0.578	1.277	0.547	0.273	6.545	0.231	1.465	
83.5	26.50	0.76	7.63	0.219	0.567	1.277	0.547	0.273	6.272	0.210	1.360	*Dead Storage*
83	26.00	0.74	7.25	0.236	0.557	1.276	0.546	0.545	5.998	0.190	1.255	
82	25.00	0.70	6.54	0.272	0.535	1.272	0.545	0.543	5.453	0.152	1.084	
81	24.00	0.66	5.86	0.309	0.514	1.266	0.542	0.540	4.910	0.117	0.950	
80	23.00	0.62	5.22	0.349	0.493	1.258	0.538	0.536	4.369	0.085	0.849	
79	22.00	0.60	4.60	0.381	0.471	1.247	0.534	0.531	3.833	0.070	0.771	
78	21.00	0.56	4.02	0.435	0.450	1.234	0.529	0.525	3.302	0.030	0.721	
77	20.00	0.52	3.48	0.487	0.428	1.220	0.522	0.518	2.777	0.000	0.000	New zero depth
76	19.00	0.46	2.99	0.582	0.407	1.202	0.515	0.511				
75	18.00	0.40	2.57	0.689	0.385	1.183	0.506	0.502				
74	17.00	0.35	2.20	0.813	0.364	1.161	0.497	0.492				
73	16.00	0.30	1.87	0.955	0.343	1.137	0.487	0.481				
72	15.00	0.26	1.59	1.117	0.321	1.111	0.475	0.469				
71	14.00	0.23	1.34	1.303	0.300	1.081	0.463	0.456				
70	13.00	0.20	1.12	1.516	0.278	1.050	0.449	0.442				
69	12.00	0.18	0.94	1.760	0.257	1.015	0.435	0.426				
68	11.00	0.15	0.77	2.040	0.236	0.977	0.418	0.410				
67	10.00	0.14	0.62	2.236	0.214	0.936	0.401	0.391				
66	9.00	0.12	0.49	2.729	0.193	0.891	0.382	0.371				
65	8.00	0.10	0.39	3.279	0.171	0.842	0.361	0.349				
64	7.00	0.09	0.30	3.629	0.150	0.789	0.338	0.325				
63	6.00	0.08	0.22	4.182	0.128	0.730	0.312	0.298				
62	5.00	0.07	0.15	4.652	0.107	0.664	0.284	0.269				
61	4.00	0.04	0.09	7.589	0.086	0.591	0.253	0.235				
60	3.00	0.03	0.05	9.983	0.064	0.506	0.217	0.195				
59	2.00	0.03	0.02	10.438	0.043	0.405	0.174	0.146				
58	1.00	0.004	0.002	73.692	0.021	0.276	0.118	0.059				
57	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000				

doi: 10.14710/teknik.v46i2.65307

Based on the sediment distribution calculation results in Table 10, the new zero-depth elevation is determined to be +77.00 m. After 50 years of operation (T50), the volume of sediment deposited in the Kuwil Kawangkoan Reservoir is estimated to reach 15.369 million m³. This sediment is divided into several parts: 6.27 million m³ in dead storage, 8.17 million m³ in effective storage, and 0.93 million m³ in flood storage. These changes can be seen in Table 11.

Table 11. Changes in Storage Volume of Kuwil Kawangkoan Reservoir after 50 Years of Operation

Description	**Initial Storage (T_0) (million m^3)**	**Sediment Storage (million m^3)**	**Final Storage (T_{50}) (million m^3)**
Flood Storage	5.94	0.93	5.01
	100.00 %	15.61 %	84.39 %
Effective storage	19.26	8.17	10.77
	100.00 %	42.42 %	57.58 %
Dead Storage	7.63	6.27	1.36
	100.00 %	82.18 %	17.82 %

Based on Table 11, the dead storage volume of the Kuwil Kawangkoan Reservoir will be reduced to 17.82% of its initial capacity. The original dead storage capacity of 7.63 million m³ will decrease to 1.36 million m³ at an elevation of +77.00 m. However, since the reservoir intake elevation is at +83.50 m, the reservoir's operation in meeting downstream water demands is expected to remain unaffected for the next 50 years.

The reservoir's volume will be impacted if sedimentation increases from an elevation of +77.00 m to near +83.50 m (the intake elevation). In such a case, the reservoir could lose its function as a water supplier, potentially disrupting the water supply and even clogging the intake.

The comparative curve of the reservoir's initial storage capacity (T0) and after 50 years of operation (T50) can be seen in Figure 11.

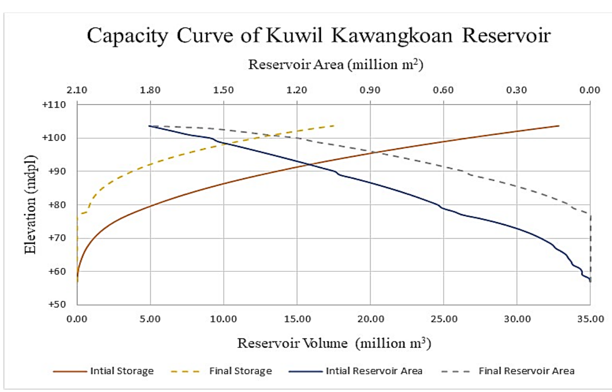

Figure 11. Initial (T_0) and Final (T_{50}) Storage Capacity Curves of the Kuwil Kawangkoan Reservoir

3.4 Mitigation of Reservoir Sedimentation

The reservoir sedimentation mitigation strategy encompasses a multifaceted approach to watershed management, including the reforestation of critical lands to mitigate erosion, the construction of check dams to enhance trap efficiency and retain sediment before its entry into the reservoir, and the implementation of regular bathymetric surveys for the monitoring of sediment accumulation. These measures collectively contribute to the management of sediment buildup, thereby extending the lifespan of the reservoir.

4. Conclusion

The erosion rate in the Kuwil Kawangkoan Reservoir catchment area is 52.77 tons/ha/year or 2,155,164.67 tons/year. The total erosion rate resulted in sedimentation deposits in the Kuwil Kawangkoan Reservoir of 307,382.08 m^3/year. For the operation period of the reservoir for 50 years, the sediment deposited amounted to 15,369 million m^3. The sediment will settle in the dead storage of 6.27 million m^3, effective storage of 8.17 million m^3 and flood storage of 0.93 million m^3. This sediment volume will cause the remaining reservoir dead storage to be 17.82%, effective storage to be 57.58%, and flood storage to be 84.39%. The change in reservoir storage volume does not relatively affect the water demand downstream of Kuwil Kawangkoan Reservoir after 50 years of operation.

Acknowledgment

The author would like to thank the Sulawesi River Basin I Manado for helping with data needs in the implementation of this study so that this study can be completed.

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doi: 10.14710/teknik.v46i2.65307