http://ejournal.seaninstitute.or.id/index.php/Ekonomi
Jurnal Ekonomi, Volume 12, No 03, 2023
ISSN: 2301-6280 (print) ISSN: 2721-9879 (online)

MANGGAR DAM RISK ASSESSMENT BASED ON THE ANDERSEN MODIFICATION METHOD

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ARTICLE INFO

Keywords :
Dam,
Risk Assessment,
Modified Andersen,
Manggar

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ABSTRACT

Dams are massive water structures built for a spesific purpose, usually used for irrigation, raw water, flood control, and hydropower. Besides having great benefits also have the potential for failure as well. With such a large failure potential, the dam must continue to be monitored and maintained by carrying out Routine Operation and Maintenance activities. With the data obtained during the operation and Maintenance activites, we can anticipate the potential dam failure by conducting a Risk Assessment. Risk Assessment is used to determine repair and rehabilitation priorities that are balanced with budget availability and restore the service function of the dam. Manggar Dam is a dam that built by damming the Manngar Besar River. The Manggar Dam is located on the Manggar Besar River under the River Basin Unit (BWS) Kalimantan III in East Kalimantan Province. The method used in this research is Modified Andersen, wich is based on technical characteristics, safety plans, and the existing conditions of the dam. Using Inspection data that BWS Kalimantan III and Dam Office get. With visual inspections in the field, results of major inspection reports, and other technical documents. The results of this study indicate that the Manggar Dam is an old dam that has been repaired and built to enlarge its capacity. With the Andersen Modification method, the Manggar Dam gets a Total Risk Index Score (IRtot) of 19, wich means that the dam is in good condition and has a low risk of failure. There are only a few improvements that need to be made.

1. INTRODUCTION

Dams are large water buildings built in several purposes such as hydroelectric power plants (PLTA), natural attractions, flood control, and irrigation. Besides having great benefits for humans, dams also have great potential for failure. Dam failure is a huge danger that can cause many fatalities. economic, as well as material losses. On the other hand, some dams in Indonesia are close to and/or have passed their service life. In addition, the influence of climate change and land use changes affect the sedimentation rate that occurs and can reduce the life of the design that should be. With such a big risk, the government in an effort to maintain the function of the dam requires good risk management. The mandate of the Law of the Republic of Indonesia Number 24 of 2007 concerning Disaster Management Article 40 that every development activity that has a high risk that causes disasters is equipped with a disaster risk analysis as part of disaster management efforts. The obligation of disaster risk analysis in detail is mentioned in Government Regulation Number 21 of 2008 concerning the Implementation of Disaster Management article 12. In the Minister of Public Works No. 27 of 2015, it is stated that the management of dams and their reservoirs for water resources management is aimed at ensuring the sustainability of the functions and benefits of dams and their reservoirs, the effectiveness and efficiency of water utilization, and the safety of dams. It is continued that the management stages are in the form of operation and maintenance, change or rehabilitation, and elimination of functions (Minister of Public Works No. 27, 2015). In accordance with the mandate mentioned above, it is necessary to carry out repairs or routine inspections in order to increase the service life of existing dams in Indonesia. The need for improvement is contrary to the availability of existing budget to the Government. Therefore, it is necessary to assess the risk of existing dams in Indonesia by determining the risk class of the dam followed by prioritizing repairs carried out in order to maintain the safety of the dam. Risk assessment is expected to be able to provide an overview to stakeholders in choosing the right action in decision making when there is a potential hazard at the dam.

According to Yuliningtyas et al (2016), risk assessment can provide another way for problems that cannot be solved by traditional engineering methods or standards. Paramudawati et al, 2020 continued to state that in dams that have been built or operated, one of the objectives of risk assessment is to determine the priority or rating of repair or rehabilitation work needed to improve safety based on the risks that exist in the dam. This prioritization is important because the budget allocation for dam maintenance activities in Indonesia is allocated to operation and maintenance activities with very limited conditions for maintenance (Soentoro et al, 2013).

According to the Directorate General of Natural Resources (2011), dam risk assessment is divided into two, namely qualitative and quantitative assessment. Suprapto et al (2021) revealed that qualitative methods explain risk considerations explicitly compared to standard methods, but do not express uncertainty in probabilities. Quantitative methods consist of reality analysis methods, monte carlo simulation, and full integration methods. Quantitative risk analysis requires a complete identification of the physical and natural conditions that will explain the dam's response, as well as a complete list of mechanisms. The simplest way is a qualitative method with an index and ranking scheme that requires consideration of security and the consequences of failure.

The Andersen Modification Method is a dam risk assessment method taken from literature made by Glen R. Andersen in 2001 entitled "*Risk Indexing Tool to Assist in Prioritizing Improvements to Embankment Dam Inventories*" which is included in the risk level index method due to urugan dam collapse. This method is suitable for use in dams that have limited information about instrumentation and conditions during construction. According to Andersen et al, (2001) the risk index used is based after identifying potential failures in the physical condition of dams and the overall ranking of these failures in structural safety aspects. A list of inspections is presented for on-site inspection and to determine the physical condition of the sat. These conditions are defined in terms of condition functions that are based on the indexing scale of the condition. The four main failure modes considered are (1) overtopping (2) external erosion (3) piping (4) mass movement (slope instability). Absolute odds are specifically not taken into account in the analysis. Conditional odds are estimated for each failure mode using a Bayesian update procedure based on dam attributes. This method allows to assist in prioritizing maintenance and repair so that it is related to cost effectiveness.

2. METHODS

The research location of the Manggar Dam is located in the Manggar Besar River, Karang Joang Village, North Balikpapan District, Balikpapan City, East Kalimantan Province, which originates in the Manggar Besar River and Bemuara in the Makassar Strait, which is 11.5 Km from Balikpapan City.

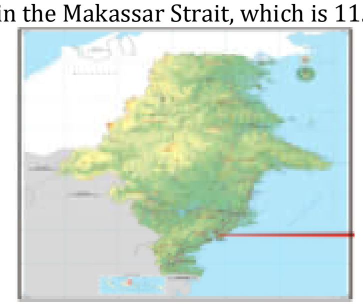

Figure 1 Location of Manggar Dam in East Kalimantan Province

Figure 2 Current Condition of Manggar Dam in Aerial Photos

As shown in Figures 1 and 2. Geographically, the location is located at coordinates 1º8'56" North Latitude and 116º54'11" East Longitude. Kutai Karta Negara Regency borders the north, the south is bordered by the Makassar Strait, the Makassar Strait borders the east, Sand Regency borders the west. Manggar Dam is an earthen dam with a dam height of 13 m, a dam width of 6 m, and a length of 350 m and a reservoir of 14.2 million m^3. With a watershed area of 50.00 km2, with rainfall of 2,636 mm with a discharge of Q100 313.15 m3/s, a discharge of Q1000 of 416.37 m3/s and a discharge of QPMF of 861.02 m3/s. This dam is a side spillway type without a door with type IV energy dampers. This dam was first built in 1984 and has been operated in 1986 which in a period of almost 40 years, the dam has undergone many events and changes that may affect the safety of the dam. The dam was upgraded because the water demand in Balikpapan city was getting bigger in 1997. Because of these conditions, a risk assessment is used to determine the risk class of the dam, determine the priority of repair and rehabilitation balanced with budget availability, and restore the service function of the dam. The method used in this method is the Andersen motifation method.

This method uses several parameters of technical characteristics, security planning, and existing conditions. These parameters consist of various factors including the technical physical condition of the dam in the form of reservoir capacity, dam height, the impact of downstream failures, instrument recording and monitoring, data availability and emergency response plans. The flow chart of the Andersen method is presented in Figure 3 below.

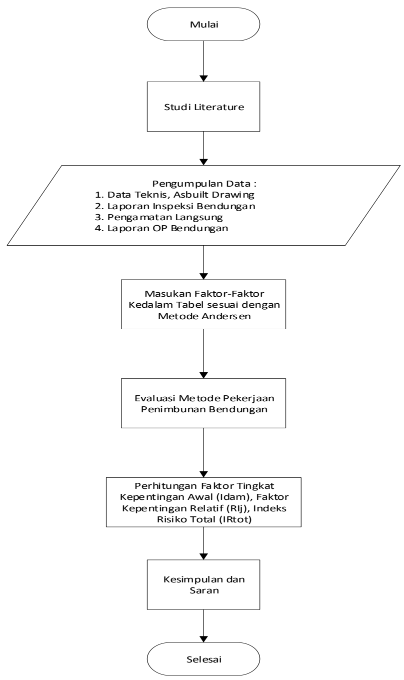

Figure 3 Andersen Method Flow Chart

1. Data Collection

The data used from this study are dam technical data, design and construction information, operation and maintenance manual reports, large inspection reports of the Manggar Dam, demographic, geographical and socio-economic data, and discussions with dam managers. Data was obtained from BWS Kalimantan III as the manager of the Manggar Dam.

Some photos of the condition of the Manggar Dam as below.


Figure 3 Dam Peak Conditions

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Jurnal Ekonomi, Volume 12, No 03, 2023
ISSN: 2301-6280 (print) ISSN: 2721-9879 (online)


Figure 4 Condition of the Upstream Slope of the Dam


Figure 5 Downstream Slope Conditions of the Dam


Figure 6 Dam Spillway Conditions

Figure 7 Dam Intake Conditions


Figure 8 Water Conditions of Manggar Reservoir

1. Andersen Modification Method
   In the Andersen modification method there are 10 vulnerability function factors whose results are obtained from large inspections and direct observations in the field, these results are entered into several tables. The 8 vulnerability function factors in question are:
   a. Internal Characteristic Factor of Dam Height in Meters (I1)

Table 1 Dam Height Factors in Meters

Height of dam [m (ft)] (1)	Score (2)
<2.7 (<9)	1
2.7–12.2 (9–40)	3
12.2–30.5 (40–100)	6
>30.5 (>100)	10

Note: Ranges and scores can be modified for specific owner requirements.

b. Dam Type Internal Characteristic Factor (I2)

Table 2 Dam Type Factors

Type of dam (1)	Description (2)	Score (3)
Rockfill	Composed primarily of cobble or larger sized particles	4
Earthfill	Composed primarily of gravel, sand, and/or silt and clay sized particles	10

c. Foundation Type Internal Characteristic Factor (I3)

Table 3 Foundation Type Factors

Type of foundation (1)	Score (2)
Rock	1
Moraine	5
Alluvium	10

d. Internal Characteristic Factors of Reservoir Capacity (I4)

Table 4 Reservoir Capacity Factors

Storage capacity [ha·m (acre-ft)] (1)	Score (2)
<6.17 (<50)	1
6.17–123 (50–999)	3
123–6,170 (1,000–50,000)	6
>6,170 (>50,000)	10

Note: Ranges are in accordance with summarized ranges published by FEMA (1998). Actual ranges could be modified to reflect particular inventory within state or jurisdiction.

e. Internal Characteristic Factors of Reservoir Age (E1)

Table 5 Age Factors of Reservoirs

Age of dam (years) (1)	Score (2)
0–9	10
10–29	8
30–59	5
60–99	2
>100	1

f. External Seismity Characteristic Factors (E2)

Table 6 Seismic Factors

Modified Mercalli Intensity (1)	Score (2)
V or lower	1
VI	2
VII	6
VIII	8
IX	10

Note: Uniform Building Code seismic zones or other relevant seismic criteria could be used in place of modified Mercalli Intensity scale.

g. Spillway Capacity Characteristic Factor (D1)

Table 7 Spillway Capacity Factors

Conditions (1)	Score (2)
(a) Known conditions	
Spillway capacity is less than half the required capacity	10
Spillway capacity is greater than half the required capacity	5
Spillway capacity is greater than required	1
(b) Suspected conditions	
Spillway capacity is less than required	5
Spillway capacity is greater than required	2

Note: Only select known conditions if a hydrologic and hydraulic analysis has been performed.

h. Characteristic Factor of Safe Deformation Number (D2)

Table 8 Deformation Safe Number Factors

Conditions (1)	Score (2)
(a) Known conditions	
Spillway capacity is less than half the required capacity	10
Spillway capacity is greater than half the required capacity	5
Spillway capacity is greater than required	1
(b) Suspected conditions	
Spillway capacity is less than required	3
Spillway capacity is greater than required	2

Note: Only select known conditions if a hydrologic and hydraulic analysis has been performed.

The parameters mentioned above are entered into the Formula as follows:

$$V = \frac{(I_1 + I_2 + I_3 + I_4)}{4} \frac{(E_1 + E_2)}{2} \frac{(D_1 + D_2)}{2}$$

Where V is the Total Vulnerability Factor. After obtaining the value of V in the risk analysis of the andersen method, there is a value of the potential hazard range (H). There are three ranges of high potential hazards with a score of 10 classified in terms of potential loss of life, medium with a score of 5 with large economic losses, and low with a score of 1 which are classified as not causing loss of life and large economic losses. After obtaining these two values, V and H are found the value of the Dam Importance Level (Idam) in the following formula:

$$I_{Dam} = V \times H$$

With a maximum Craving value is 10,000. After obtaining the Idam value, it is continued by taking into account the consideration of the direct physical conditions contained in the dam. This must be done directly in the field or by looking at a large inspection report with BWS Kalimantan III and Balai Damungan. 9 physical conditions can cause a dam to burst according to the Andersen risk analysis method. The factors are as follows:

1) Loss of spillway capacity
2) Erosion on spillways
3) Loss of outlet work function
4) Dam height loss
5) Loss of embankment surface protective material
6) Piping on embankments or along outlets
7) Piping on the foundation
8) Landslide on embankment
9) Landslides on foundations and embankments.

Of the 9 failure factors, they are condensed into 4 failure factors that often occur in urugan type dams. The shrinking of the above factors can be seen in the picture below.

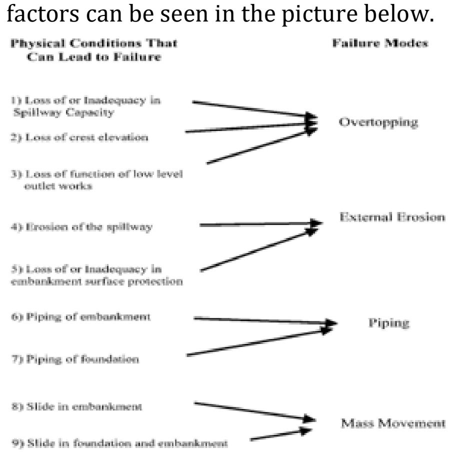

Figure 4 Failure Factor Merger

The relative importance factor of the dam is derived from the following equation:

$$RI_j = P[M_i | F] \times P[C_j | M_i] \times I_{dam}$$

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Jurnal Ekonomi, Volume 12, No 03, 2023
ISSN: 2301-6280 (print) ISSN: 2721-9879 (online)
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Where RIj is the relative importance factor of the physical condition to j, P[MiIF] is the conditional probability of the variety of failures to i, P[CjIMi] is the conditional probability of the physical condition to j. The paremeter is a mixture of parameters that are very difficult to obtain. This is due to limited data on dam failure in Indonesia, so careful analysis has not been carried out. The 9 factors are as follows along with the table:

a. Spillway obstruction (CF1)

Table 9 Physical Condition of Spillway Capacity Inspection

Indicator (1)	Suggested condition range (2)
Part of the spillway cross section if obstructed	
0–10% obstructed	7–10
10–25% obstructed	4–7
>25% obstructed	0–4
Note: In the absence of any obstruction assign a condition of 10.	

b. High reduction in care (CF2)

Table 10 Physical Condition of Maintenance Height Reduction Capacity Inspection

Indicator (1)	Suggested condition range (2)
Deviations from original crest elevation in terms of loss of designed or estimated freeboard	
0–10% loss	7–10
10–25% loss	4–7
>25% loss	0–4
Trees on or near crest	0–5
Note: In the absence of either indicator assign a condition of 10.	

c. Dispensing channel barrier (CF3)

Table 11 Physical Condition of Inspection of Barriers in Outlet Channels

Indicator (1)	Suggested condition range (2)
Obstructions in cross section of outlet pipes	
0–10% obstructed	7–10
10–25% obstructed	4–7
>25% obstructed	0–4
Suspected but unverified obstruction	7–10
Valves and gates for outlet works	
Functioning properly or recently repaired	6–10
Not operated recently	0–5
Owner not willing to exercise valves and gates	0–1
Valves and gates cannot be opened	0
Note: In absence of any indicator assign a condition of 10. If there is no low-level outlet then do not consider.	

d. Erosion of spillways (CF4)

Table 12 Physical Condition of Spillway Erosion Inspection

Indicator (1)	Suggested condition range (2)
Observed erosion/deterioration of spillway channel	
None to minor	7–10
Some to moderate	4–7
Serious to extensive	1–4
Critical with sill lost	0
Note: In absence of any erosion or deterioration assign a condition of 10.	

e. Protective material on dam surface (CF5)

Table 13 Physical Conditions of Inspection of Protective Materials on Dam Surfaces

Indicator (1)	Suggested condition range (2)
Loss of upstream slope protection	
None to isolated and moderate loss or degradation	4–10
Serious to extensive loss or degradation	1–4
Critical loss or degradation (esposure of bedding material)	0
Loss of embankment surface material	
Slight [0–0.3 m (0–1 ft)]	7–10
Moderate [0.3–0.6 m (1–2 ft)]	5–7
Extreme >0.6 m (>2 ft)	0–5
Note: In event of no loss of surface protection material assign a condition of 10.	

f. Reed erosion of the dam body (CF6)

Table 14 Physical Condition of Reed Erosion Inspection on Weir Body

Indicator (1)	Suggested condition range (2)
Turbid flows	
Evidence of prior occurrence that has gone uncorrected	2–7
Actively occurring	0–2
Sinkholes or depressions on the surface of dam	0–5
Build-up of pore water pressure in embankment as inferred by uncontrolled seepage areas	
Changes in surface vegetation	5–10
Soft/wet areas on the surface	4–8
Constant surface flow	2–7
Increasing surface flow	0–4
Stumps and root systems left in place on embankment or small animal burrows present	0–5
Note: In absence of any indicator, assign a condition of 10.	

g. Reed erosion of dam foundations (CF7)

Table 15 Physical Condition of Dam Body Stability Inspection

Indicator (1)	Suggested condition range (2)
Turbid flows	
Evidence of prior occurrence	2–7
Actively occurring	0–2
Sinkholes or depressions on dam, toe, or abutments	0–5
Buildup of pore water pressure in foundation as inferred by uncontrolled seepage areas in toe and abutment areas	
Changes in surface vegetation	5–10
Soft/wet areas on surface	4–8
Constant surface flow	2–7
Increasing surface flow	0–4
Note: In the absence of any indicator assign a condition of 10.	

h. Dam body stability (CF8)

Table 16 Physical Condition of Dam Body and Foundation Stability Inspection

Indicator (1)	Suggested condition range (2)
Buildup of pore water pressure in embankment as inferred by uncontrolled seepage areas	
Changes in surface vegetation	5–10
Soft/wet areas on the surface	4–8
Constant surface flow	2–7
Increasing surface flow	0–4
Surface evidence of impending mass movement such as cracking, shallow slides, and differential movement in the embankment or between the embankment and foundation	
Minor and localized	2–8
Major and extensive	0–2
Note: In the absence of any indicator assign a condition of 10.	

i. Dam body stability and foundation (CF9)

Table 17 Physical Condition of Dam Body and Foundation Stability Inspection

Indicator (1)	Suggested condition range (2)
Buildup of pore water pressure in embankment and foundation as inferred by uncontrolled seepage areas	
Changes in surface vegetation	5–10
Soft/wet areas on the surface	4–8
Constant surface flow	2–7
Increasing surface flow	0–4
Surface evidence of impending mass movement such as cracking, shallow slides, and bulging	
Minor and localized	2–8
Major and extensive	0–2
Note: In the absence of any indicator assign a condition of 10.	

After all these values are obtained, just look for the Total Risk Index (IRtot) value. The Total Risk Index is a factor that describes dam risk, obtained by combining the weighted value of field conditions (CFi) with the relative importance factor using the following equation :

$$IR_j = RI_j \times (10 - CF_j) / 10$$

$$IR_{tot} = \Sigma IR_j$$

Where CFj is the weight of the field condition to j. The prioritization of the risk level of the Andersen modification method is determined based on the order of the largest total risk index (IRtot).

3. RESULTS AND DISCUSSION

Risk assessment of the Manggar dam Andersen modification method based on the latest Manggar Dam Inspection Report in 2018. The Risk Index assessment of the Andersen Modified Method is as follows:

Table 18 Calculation of Manggar Dam Idam

No	Kriteria	Kode	Data Bendungan	Score
1	Tinggi Bendungan	I1	12,6	6
2	Tipe Bendungan	I2	Urugan Tanah	10
3	Tipe Pondasi	I3	Batuan	1
4	Kapasitas Waduk	I4	13230,9	6
5	Umur Waduk	E1	38	5
6	Seismitas	E2	5	1
7	Kapasitas Spillway	D1	> QPMF	1
8	SF Deformasi	D2	SF > 2.35	1
9	V			17,25
10	H		Potensi Kehilangan Nyawa	10
11	I dam		V x H	172,5

After obtaining the value of *Importance of Dam* (Idam) continued by determining the value of the Relative Importance Factor. The conditional probability value of the variety of failures to i, P [Mi I F] is obtained from direct observations in the field, and the report is contained in the inspection report of the Manggar Dam. These values are condensed in 4 failure criteria for *overtopping, external erosion, piping, and mass movement.* The possibility of failure of the Manggar Dam after seeing from the field inspection report found the possibility of failure due to *overtopping* by 40%, failure with *external erosion* by 30%, failure due to *piping* is 20% and failure due to *mass movement* by 10%. So the value of P[Mi I F] is as follows as in Table 19.

Table 19 Conditional Probability Values of Failure Variety (P[Mi I F])

No	Kriteria	Kode	Keterangan Data Bendungan	Nilai
1	Overtopping	PMiF1	Tidak ada Penghalang	40
2	Overtopping	PMiF2	Terdapat Keretakan Minor	40
3	Overtopping	PMiF3	Terdapat sedikit halangan	40
4	External Erosion	PMiF4	Tidak ada	30
5	External Erosion	PMiF5	Terdapat Retakan	30
6	Piping	PMiF6	Tidak ada	20
7	Piping	PMiF7	Tidak ada	20
8	Mass Movement	PMiF8	Minor Cracking	10
9	Mass Movement	PMiF9	Minor Cracking	10

After finding the value of P [Mi I F] according to the conditions in the field and shown in the table above, then proceed to find the conditional probability value in physical conditions to j P [Cj I Mi].

Table 20 Conditional Probability Values on Physical Conditions to J (P[Cj I Mi])

No	Kriteria	Kode	Keterangan Data Bendungan	Nilai
1	Penghalang pada saluran pelimpah	PCjMi1	Tidak ada Penghalang	10
2	Pengurangan tinggi jagaan	PCjMi2	Terdapat Keretakan Minor	40
3	Penghalang pada saluran pengeluaran	PCjMi3	Terdapat sedikit halangan	50
4	Erosi pada saluran pelimpah	PCjMi4	Tidak ada	40
5	Material pelindung pada permukaan bendungan	PCjMi5	Terdapat Retakan	60
6	Erosi buluh pada tubuh bendungan	PCjMi6	Tidak ada	70
7	Erosi buluh pada fondasi bendungan	PCjMi7	Tidak ada	30
8	Stabilitas tubuh bendungan	PCjMi8	Minor Cracking	50
9	Stabilitas tubuh dan fondasi bendungan	PCjMi9	Minor Cracking	50

After obtaining this value, it is entered in the RIj equation, after that we determine the value of the weight of the field condition to j, with symbols CF1 to CF9 as in the table below.

Table 21 Field Condition Weight Value to j (CFj)

No	Kriteria	Kode	Keterangan Data Bendungan	Nilai
1	Penghalang pada saluran pelimpah	CF1	Tidak ada Penghalang	9,5
2	Pengurangan tinggi jagaan	CF2	Terdapat Keretakan Minor	9,5
3	Penghalang pada saluran pengeluaran	CF3	Terdapat sedikit halangan	9
4	Erosi pada saluran pelimpah	CF4	Tidak ada	9
5	Material pelindung pada permukaan bendungan	CF5	Terdapat Retakan	9
6	Erosi buluh pada tubuh bendungan	CF6	Tidak ada	8
7	Erosi buluh pada fondasi bendungan	CF7	Tidak ada	8
8	Stabilitas tubuh bendungan	CF8	Minor Cracking	9
9	Stabilitas tubuh dan fondasi bendungan	CF9	Minor Cracking	9

After all factors are met, the equation can be entered to find the value of the Ratio Index (Rij). The value (Rij) is mentioned in the table below.

Table 22 Index Values of the Ratio to j (RiJ)

No	Kriteria	Kode	Keterangan Data Bendungan	Nilai
1	Penghalang pada saluran pelimpah	Rij1	Tidak ada Penghalang	6,9
2	pengurangan tinggi jagaan	Rij2	Terdapat Keretakan Minor	27,6
3	penghalang pada saluran pengeluaran	Rij3	Terdapat sedikit halangan	34,5
4	erosi pada saluran pelimpah	Rij4	Tidak ada	20,7
5	material pelindung pada permukaan bendungan	Rij5	Terdapat Retakan	31,1
6	erosi buluh pada tubuh bendungan	Rij6	Tidak ada	24,2
7	erosi buluh pada fondasi bendungan	Rij7	Tidak ada	10,4
8	stabilitas tubuh bendungan	Rij8	Minor Cracking	8,63
9	stabilitas tubuh dan fondasi bendungan	Rij9	Minor Cracking	8,63

The value of the Ratio Index (Ri) will be added up and the Total Ratio Index value is obtained. The value of the Total Manggar Dam Ratio Index is in the table below.

No	Kriteria	Kode	Keterangan Data Bendungan	Nilai
1	Penghalang pada saluran pelimpah	IRj1	Tidak ada Penghalang	0,35
2	pengurangan tinggi jagaan	IRj2	Terdapat Keretakan Minor	1,38
3	penghalang pada saluran pengeluaran	IRj3	Terdapat sedikit halangan	3,45
4	erosi pada saluran pelimpah	IRj4	Tidak ada	2,07
5	material pelindung pada permukaan bendungan	IRj5	Terdapat Retakan	3,11
6	erosi buluh pada tubuh bendungan	IRj6	Tidak ada	4,83
7	erosi buluh pada fondasi bendungan	IRj7	Tidak ada	2,07
8	stabilitas tubuh bendungan	IRj8	Minor Cracking	0,86
9	stabilitas tubuh dan fondasi bendungan	IRj9	Minor Cracking	0,86
Indeks Rasio Total (IRtot) Bendungan Pacal				19

It was found that the total IRvalue for the Manggar Dam was 19. According to Dery Indrawan, Mahdi Ibrahim Tanjung, and Nurlia Sadikin in the Risk Index Assessment of the Andersen Modification Method and ICOLD Modification for 12 Dams in Java, the IRtot value can indicate the priority of improvement on the dam. The smaller the Total Ratio Index (IRtot) value, the less damage indicates that the dam is still in excellent condition. The dam is in excellent condition only needs regular maintenance and normal operation.

4. CONCLUSION

Based on the risk assessment of Andersen's modification method, the Manggar Dam is an old dam that has been repaired and built to enlarge the reservoir. The dam received a Total Risk Index score of 19 which means that the dam is in good condition and has a low risk of failure. There are very few improvements that need to be made.

Acknowledgment

The author would like to express his gratitude to the Kalimantan River Basin Center III, the Master of Civil Engineering Study Program, Faculty of Engineering, Diponegoro University, lecturers who have taught material related to dam risk assessment, and other parties who helped and provided data support and discussion in completing this paper. The author hopes that the study conducted will be useful in the implementation of dam operation and maintenance and other academic interests.

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