SUITABILITY CONSERVATION TYPES ANALYSIS of PANGLIMA BESAR SOEDIRMAN RESERVOIR

Abstract. Mrica Reservoir located in Banjarnegara Regency is a multipurpose reservoir. Based on the report of PT Indonesia Power Unit Generator (UP) Mrica in 2016, the sediment of Mrica Reservoir has entered the critical phase because it has reached 114,25 million m^3 and the value of index land cover production of Mrica reservoir has reached 80% from total area of waatershed with the average sedimentation rate reaches 4.09 million m^3 per year and it is estimated that the reservoir will be full of sediment by 2021. The main cause of the high rate of sedimentation in the Mrica reservoir is due to the changes in land use and agricultural-plantation activities in the upper river areas and along the river flow of Serayu River, Merawu River and Lumajang River. This study aims to determine the appropriate type of conservation for Mrica Reservoir. The method used is the Analytical Hierarchy Process (AHP) method, where the determination of conservation efforts is based on secondary data and observation. Based on the condition of the current Mrica Reservoir, then planned conservation efforts in two types, namely non-structural conservation and structural conservation. If the conservation begins in 2019 the total sediment in 2021 decreases to 74% and predicted the sediment will be exhausted in 2056.

Keywords: reservoir; sediment; land use change; conservation

1 INTRODUCTION

Panglima Besar Jenderal Soedirman Reservoir or also known as Mrica Reservoir in Banjarnegara Regency is a multipurpose dam. In addition to functioning as a hydroelectric power plant (PLTA), this reservoir is also a source of water for rice field irrigation, fishery systems for fish ponds and tourism objects. This reservoir has an installed electricity capacity of 180.93 MW with a water catchment area (DTA) of 957 km^2 and an initial capacity of 148.29 million m^3. With a sedimentation rate of 2.4 million m^3 / year, at the beginning, the reservoir planning is expected to be able to operate around 60 years where the operational life of the reservoir will end in 2049 (Wulandari, 2007).

Sedimentation has an impact on the decline in capacity and operational life of the reservoir so that an effective reservoir management system is needed. When there is heavy rainfall, the entire watershed flows a lot of sediment due to erosion on the edge of the river flow. The soil from erosion collected in the reservoir has some serious impacts on the reservoir, including the reduction of reservoir volume, the formation of delta around the reservoir, changes in river flow, loss of energy, and damage to the inlet and outlet of the reservoir which affects the reservoir working system (Zende, 2018).

The amount of sediment entering the reservoir causes high accumulation of sediment in the reservoir and makes the reservoir shallow. The silting of the reservoir caused the reservoir to be shallow so there was less reservoir capacity for water. This has an impact on the function of the reservoir, such as the provision of water for electricity generation, raw water, irrigation, flood control and so on. Besides that, the amount of sediment in the reservoir gives a greater burden on the construction of the reservoir so that it affects the operational life of the reservoir (Wahyudi, 2004).

Based on a report by PT Indonesia Power Unit Pembangkitan (UP) Mrica in 2016, the Mrica reservoir sediments have entered a critical phase because they have reached 110.69 million m^3 or about 75% of the reservoir volume, with an average sedimentation rate from the initial year of operation in 1988 to in 2015 amounting to 4.09 million m^3. This condition will certainly reduce the operational life of the reservoir to only half of the original plan, which is only about 30 years, this is due to the fact that the actual sedimentation on average almost twice than the sedimentation plan. Conservation activities have been carried out by PT Indonesia Power UP Mrica such as sediment flushing using Drawdown Culvert (DDC), ejecting flushing through spillway, and reforestation in the upper reaches of the Mrica watershed, but the results are still not effective in suppressing the rate of sedimentation even considered detrimental to the company due to flushing using DDC and spillway require a lot of water, with a ratio of the amount of sediment discharged and the water needed is 1:10. This condition forced PT Indonesia Power UP Mrica, the Regional Government of Banjarnegara Regency, the Community and various related elements to work together to overcome the problem of sedimentation of the Mrica Reservoir (Darsono, 2016).

Based on this problem, a special study is needed to determine the prevention of sediment rate and reservoir conservation so that later mitigation efforts can be done if the reservoir undergoes effective age degradation. It is expected that the results of this study can be used as a reference in efforts to conserve or maintain the Mrica reservoir.

2 METHOD

2.1 Data Collecting

The data used in this study is secondary data obtained from relevant agencies. The data needed in this research include:

1. inflow debit;
2. suspended load data;
3. characteristic of sediment;
4. topographic map;
5. land use map.

2.2 Data Analysis

In this study, the analysis stage was carried out by knowing the condition of the Mrica reservoir based on the data collected and observation. After that, a literature study was conducted on reservoir conservation efforts based on the characteristics and conditions of the Mrica reservoir. For the best conservation effort will be analyzed using the AHP (Analytical Hierarchy Process) method. Where the steps are as follows:

A. Develop a hierarchical structure of problems.
   The main tool of the Analytical Hierarchy Process (AHP) model is the hierarchy of the problems that are resolved.
B. Make a pairwise comparison matrix.
C. Calculate the weight / priority of each variable.
   The steps are as follows:
   1) Make pairwise comparisons of each criterion.
   2) The results of each paired comparison are displayed in a pairwise comparison matrix (pairwise comparison).
   3) Share each element in a particular column with the value of the number of columns.
   4) The results are then normalized to get the eigenvector matrix by averaging the number of rows.
D. Calculate the priority of each variable.
E. After knowing the weight of each variable.

2.3 Determination of Conservation Efforts

Determination of the conservation efforts of the Mrica reservoir is divided into two parts, namely technical and conservation conservation in a non-technical manner based on the nature or extent of damage to each parameter. Technical conservation includes construction of control structures and determination of sediment dredging techniques in reservoirs. While non-technical / semi-technical conservation includes conservation activities such as handling vegetatively or socially.

3 RESULTS

3.1. Analysis of the Condition of Mrica Reservoir

The causes of erosion and sedimentation in the reservoir are due to changes in land function in the upstream, central and downstream areas of the Mrica reservoir watershed.

Table 1. Recapitulation of Changes in Land Use in Mrica DTA 2001-2009

Land Use	**2001**	**2009**	**Change**
	Km2	**Km2**	**%**
Homogeneous Forest	229.13	67.12	(-) 70.71%
Heterogeneous Forest	194.08	74.74	(-) 61.49%
Open Land	154.07	98.14	(-) 36.30%
Other Plantations	0.14	93.3	(+) 66542.86%
Tea Plantation	0.83	8.17	(+) 884.34%
Gardens / fields	91.35	317.62	(+) 247.70%

Rice Fields	15.74	54.04	(+) 243.33%
Settlement	28.66	60.8	(+) 112.14%

Sumber: Hanafi, 2015

This land change caused an increase in the rate of erosion and sedimentation in the Mrica reservoir, resulting in the occurrence of water hyacinth, increased total sediment in the reservoir, and irrigation system disruption because the amount of sediment volume increased while the volume of water in the reservoir decreased so that it affected the operational life of the Mrica reservoir. So that it needs to be handled or conserved in the upstream area or the source of erosion and in the Mrica reservoir.

Table 2. Assessment of Reservoir Conditions

Parameters	**Level of Damage**		
	Low	**Mid**	**High**
Upstream Erosion	-	-	√
Middle Erosion	-	√	-
Downstream Erosion	√	-	-
Sedimentation Rate	-	-	√
Mount of Sediment	-	-	√
Change in Land Function in Upstream	-	-	√
Total	1	1	4

Based on the assessment table above, the condition of the Mrica watershed and reservoir is included in the high level of damage. Therefore, effective conservation efforts are needed in which the conservation efforts involve the role of the community and are sustainable. Conservation management is carried out in two types, namely non-structural conservation and structural conservation.

3.2. Hierarchy Structure of Conservation Method Selection

This study has objectives, alternatives and various criteria that must be clarified its position in the hierarchical structure. The structure of the hierarchy is carried out by conducting literature studies on reservoir conservation and analysis of secondary data that has been collected previously. After a hierarchical structure is arranged, weighing the level of importance in compiling a pairwise comparison matrix is carried out. Weighting is based on the analysis of secondary data and the results of observations to the location.

The following are various hierarchical elements and structures (Figure 1) that have been determined based on the analysis of secondary data and the results of observations to the location.

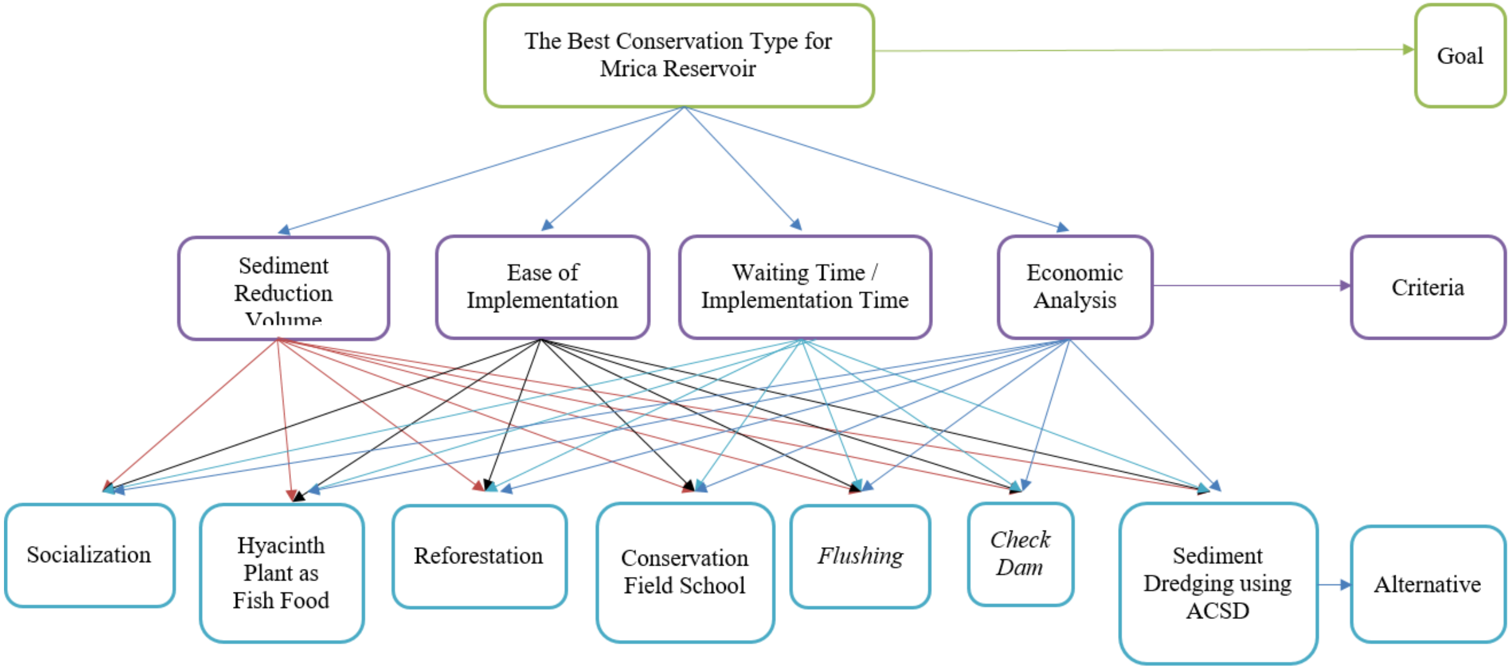


Figure 1. AHP Structure Selection of Conservation Type for Mrica Reservoir

3.3. Non-Structural Conservation

Erosion caused by several factors such as climate, topography, soil characteristics and vegetation conditions. Vegetation conditions greatly affect the level of erosion that occurs. There is a need to deal with land in the upper watershed area by improving the quality of vegetation to reduce the level of erosion that occurs, especially in areas with heavy to very heavy erosion. The function of vegetation is that it can strengthen soil structure due to the spread of plant roots, influence the flow of rainwater runoff on the surface, and increase the growth of microorganisms found in the soil. Vegetation conservation planning is carried out based on land use maps and land slope maps in the upper watershed.

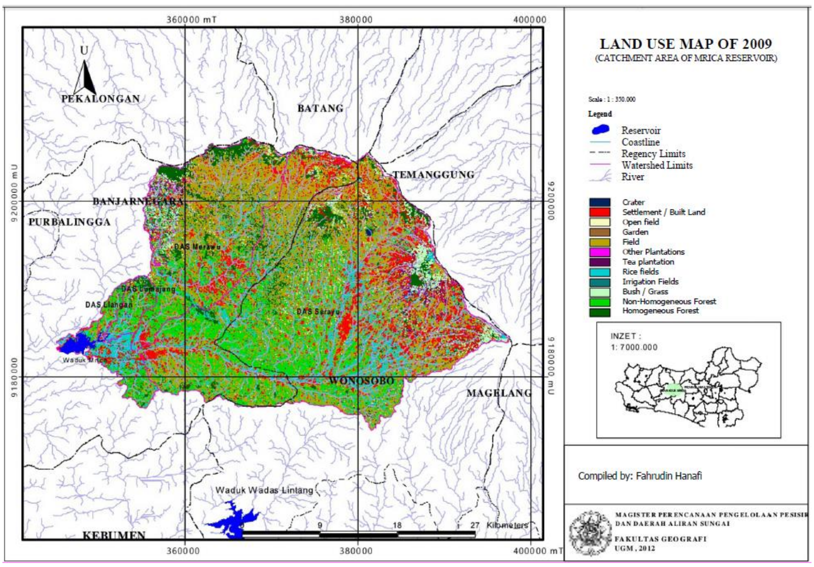


Figure 2. Land use map of 2009

The following non-structural conservation activities can be carried out to prevent the rate of erosion while improving the economic quality of the community around the watershed:

A. Socialization

The socialization activities were carried out in stages for the people in the upper watershed and around the hydropower reservoir of PB Soedirman. These socialization activities were conducted in three Mrica watersheds, such as the Serayu river, Merawu river, and Lumajang river.

Figure 3. Socialization Activity in Mrica Watersheds

B. Hyacinth Plant as Fish Food

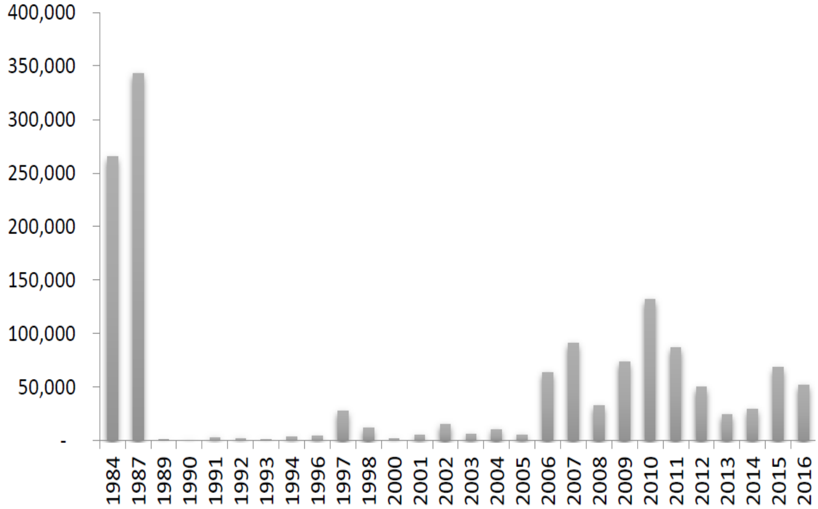
Water hyacinth plants contain nitrogen of 3.2% and have a C / N ratio of 15. The content of the water hyacinth plant is very effective to be used as herbivorous and omnivorous fish as a substitute for pellets. The use of fish can reduce hyacinth plants by 164 kg per day.

Figure 4. Fish Ponds Around Mrica Reservoir

This handling is in addition to being profitable for PT Indonesia Power UP Mrica, it can also provide economic benefits for the people in the area around the reservoir. Therefore, this activity can involve the role of the surrounding community while increasing the number of fish and the potential for handling hyacinth blooms that occur.

C. Reforestation

Reforestation is carried out in stages in the upstream of the reservoir watershed and around the Mrica reservoir. This activity involves and empowers the surrounding community. The company helps in providing tree seedlings requested by the community and later the community itself will take care and enjoy the results of the tree.



Source: PT. Indonesia Power UP Mrica, 2017

Figure 5. Reforestation Activities Report

D. Conservation Field School

This activity is a training and community empowerment activity along the Mrica watersheds with a land management/cultivation program by planting hard-trunked plants such as coffee to reduce the impact of erosion which causes sedimentation in the Mrica reservoir.

Figure 6. Conservation Field School Activities

In the conservation field school activities, coffee plants were chosen because 90% of the roots of coffee plants were concentrated in the soil layer between 0-30 cm. This results in the formation of a good root tissue in the surface layer of the soil so that the surface layer of the soil can be bonded well by the roots which causes the erosion rate to decrease even though the surface flow is large. Inland with slopes of 50% -60%, coffee plants can reduce the erosion rate by 81.08%.

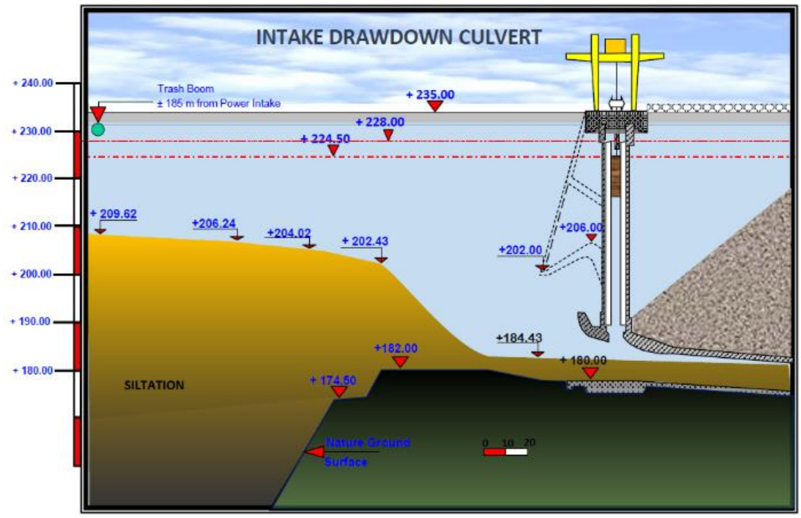
In addition to planting coffee plants, it is necessary to plant soil cover crops that aim to withstand the splashing of rainwater and the flow of water above the soil surface. The selected cover crops are sweet potato plants, this is because sweet potato plants do not have a large impact on coffee production, on the contrary, this plant is able to reduce the erosion rate up to 41.38%.

3.4. Structural Conservation

Sediment conservation is structurally carried out to effectively and efficiently manage reservoir sediments given the condition of the reservoir which has entered a critical phase. Sediment handling methods are dissected based on volume, technical and handling location. The following details on structural sediment handling:

A. Flushing

Flushing through the Drawdown Culvert (DDC) according to established procedures. Flushing as an effort to overcome sediment collection around Power Intake. Flushing is carried out only if the sediment elevation is above the DDC threshold, if it is still below then no flushing is carried out (If the sediment elevation> +187 m, then flushing immediately). Flushing is also possible if the inflow of water that enters the dam is ≥1000 m3.



Source: PT. Indonesia Power UP Mrica, 2016

Figure 7. Intake DDC in 2015

B. Check Dam

In this study, check dam construction is focused on locations with heavy and very heavy erosion rates, following the basic considerations for determining check dam locations:

Table 3. Consideration for Determining the Location of Dam Checks

No	Locations	Erosion Level	Slope
C1	Upstream	Very Heavy	>25°-45°

C2	Upstream	Very Heavy	>15° -25°
C3	Upstream	Very Heavy	>25° -45°
C4	Upstream	Very Heavy	>15° -25°
C5	Middle	Heavy	>15° -25°
C6	Middle	Very Heavy	>25° -45°
C7	Downstream	Heavy	>8°-15°
C8	Middle	Heavy	>8°-15°
C9	Middle	Heavy	>8°-15°

Based on the table above, determine the check dam location based on the level of erosion and the height of the slope. Then the location of the check dam builder is planned as follows:

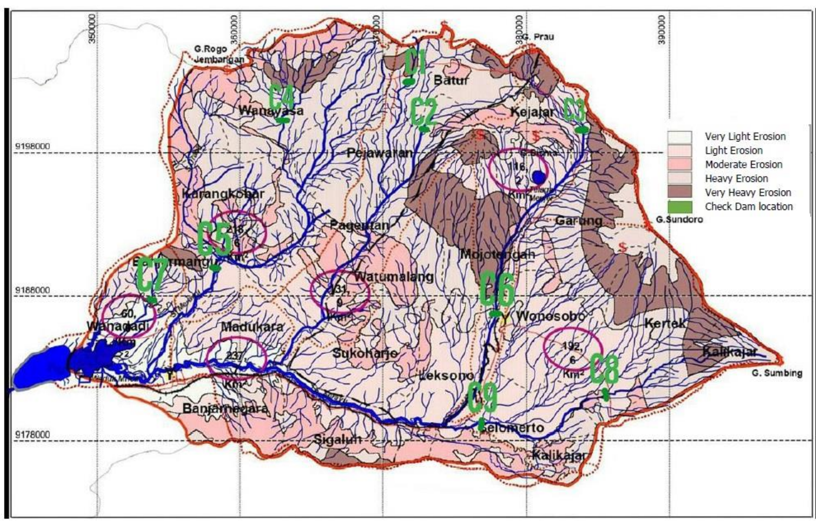


Figure 8. Map of Check Dam Location

In research conducted by Mishra (2006) and Karim (2014) using the software of Soil and Water Assessment Tool (SWAT), the use of check dam in controlling the sediment rate can reduce the sediment rate by more than 64%. Construction of check dams, besides being able to reduce the rate of erosion, can also function as a place to deviate and accommodate rainwater, so that during the dry season, farmers around can utilize check dams as a source of water for watering plants.

C. Sediment Dredging

At present the Land Closure Index of Mrica reservoir production has reached 80% of the total watershed area with an average sedimentation rate reaching 4.09 million m3 per year which is equivalent to 11.197 m3 / day and an estimated reservoir will be full of sediment by 2021, the alternative sediment dredging can be done using Auger Cutter Suction Dredger (ACSD).

Source: Dredgeyad.com

Figure 9. Auger Cutter Suction Dredger

Based on the average sedimentation rate occurring in the reservoir of 4.09 million m3 / year equivalent to 11.197 m3 / day, it is planned to procure 2 Auger Cutter Suction Dredger (ACSD) dredges with a total sediment dredging capacity of 7.008.000 m3 per year. With the procurement of 2 ACSD dredgers expected to operate in 2019, the total sediment in 2021 will be 74% of the total reservoir volume and if ACSD ships are operating over the year it is predicted that sediment will be exhausted by 2056.

3.5. Calculation of Analytical Hierarchy Process (AHP)

AHP calculation in this study is divided into 5 steps. The division of importance level scales is in accordance with the AHP scale, namely 1-9 based on secondary data analysis and observations on the comparison of each alternative with the specified criteria, namely reduction volume, ease of implementation, implementation time, and economic analysis. Following the results of the AHP matrix calculation:

0.026	0.190	0.114	0.194				Socialization	0.089
0.128	0.095	0.159	0.230		0.563		Hyacinth Plant as Fish Food	0.133
0.205	0.119	0.091	0.173		0.229		Reforestation	0.169
0.179	0.143	0.114	0.144	X	0.123	=	Conservation Field School	0.160
0.077	0.214	0.205	0.115		0.086		Flushing	0.127
0.154	0.071	0.136	0.086				Check dam	0.127
0.231	0.167	0.182	0.058				Sediment Dredging	0.195

On the basis of the results of this calculation it can be stated that the conservation method using ACSD dredger is the best choice as an alternative to handling the sediment of Mrica Reservoir with a total value of 0.195. Dredging using ACSD dredgers can reduce sediments in the reservoir by 7.008.000 m^3 per year and the dredging process can be done easily and quickly, but it requires substantial costs for procurement, operations, and maintenance. Therefore, other alternative conservation methods are still implemented to reduce the total sediment entering the reservoir, maintain the Mrica watershed and increase the economy of the community in the watershed and Mrica Reservoir.

4 CONCLUSIONS

4.1 The average sedimentation rate of Mrica reservoir is 4.09 million m3 per year. The main cause of the high rate of sedimentation in the Mrica Reservoir is due to changes in land function.where the greatest land depreciation is the land function as a homogeneous forest which reaches 71% percent.

4.2 The current condition of the Mrica reservoir has entered a critical phase where the total sediment of the reservoir has reached 114.25 million m3 (75% of the reservoir volume) with the Land Closure Index value of mrica reservoir production reaching 80% of the total watershed area.

4.3 Based on the condition of the current Mrica reservoir, then planned conservation efforts in two types, namely non-structural conservation and structural conservation. If the conservation begins in 2019 then the total sediment in 2021 decreases to 74% and predicted the sediment will be exhausted in 2056.

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