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# Optimization of Dredging Location Determination in Sutami Reservoir Using the Cut and Fill Method

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## Abstract

*The Sutami Dam is located on the Brantas River, precisely in Karangkates Village, Sumberpucung District, Malang Regency. The Sutami Dam has been in operation for fifty-one years. Based on observations in the field, the rate of sedimentation entering the Sutami Reservoir is quite high, resulting in shallowing in the reservoir storage area up to the intake gate, which can affect the performance and productive life of the reservoir. This research is conducted to evaluate the planning of mapping dredging locations, the potential sediment that can be dredged, and the increase in the volume capacity of the dredging equipment. This research uses data from bathymetry, which is then analyzed for sedimentation and scour values compared between 2019 and 2022. For soil parameter data, laboratory test results such as grain size analysis and hydrometer analysis are utilized. Data analysis using the cut-fill method in ArcMap 10.8.2 software. The results of this research show that in carrying out dredging activities in the reservoir area, it is necessary to divide the dredging location into two zones with two types of dredgers that have different specifications. To increase the dredging volume capacity in the Sutami Reservoir using the scenario of using two existing dredgers and the addition of two new dredgers, an increase in the dredging capacity in the Sutami Reservoir of 1,702,189.00 m³ per year was obtained.*

**Keyword :** *sutami reservoir; bathymetry data; sediment; suction dredger; pump*

## 1. Introduction

Sutami Dam is located on the Brantas River, precisely in Karangkates Village, Sumberpucung District, Malang Regency. Its construction took place between 1961 and 1972. Sutami Dam serves multiple purposes, including flood control by reducing the Q200-year flood discharge from 3,000 m³/s to 1,060 m³/s, and irrigation water supply by regulating the water of Sutami Reservoir together with Lahor Reservoir, providing an additional discharge of 24 m³/s for downstream irrigation during the dry season. The dam also functions as a hydroelectric power plant, generating approximately 400 million kWh of electricity per year, as well as supplying raw water for drinking, industrial use, and river maintenance. Additionally, Sutami Reservoir offers tourism benefits.

According to sedimentation rate data, the sediment inflow into Sutami Reservoir is relatively high, reaching 1.75 million m³ per year, leading to reservoir sedimentation. As a result, the effective storage capacity has declined by 61% from its planned effective storage capacity, significantly affecting the reservoir's performance and productive lifespan (Perum Jasa Tirta I, 2022b). Sedimentation issues in reservoirs must be managed and controlled to ensure their continued utilization (Andriawati et al., 2015).

Dredging activities can address sedimentation issues and help maintain both the function and lifespan of the reservoir (Cunanda et al., 2021). One of the efforts undertaken by Perum Jasa Tirta I (PJT1) includes sediment dredging using a Cutter Suction Dredger (CSD). However, the dredging activities carried out in Sutami Reservoir have not yet been optimal due to the limited dredging locations.

Bathymetric data is used in dredging planning to determine sediment volume and distribution. A comparison of digital bathymetric data for the same area over different time periods provides a method for estimating or calculating the net movement of sediment into (accretion) and out of (erosion) a study area (Chukwu Fidelis & Badejo, 2015). Bathymetric map analysis can indicate that severe sediment accumulation may occur around the dam body and spillway (Darama et

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al., 2019). The results of bathymetric analysis can be used to describe the shape and volume of the reservoir and identify shallower areas where sediment concentration is likely to be higher (Ogunlela et al., 2018).

According to Morris & Fan (2010), the selection of dredging equipment depends on several factors, including sediment volume, grain size and deposit geometry, disposal and reuse availability, water level, and environmental criteria, all of which influence the feasibility and cost of dredging. All dredging methods are expensive due to the large amount of material and equipment involved, as well as the difficulty in finding suitable locations for dredged material placement and the distance to disposal sites. However, dredging is often the only viable option for managing sediment accumulation in reservoirs.

The objective of this study is to optimize the determination of dredging locations and calculate the potential sediment that can be dredged. The results will then be analyzed to plan the selection of the appropriate dredger based on head capacity and power requirements.

## 2. Data and Methods

### 2.1 Data Used

The data used in this study consists of primary data in the form of bathymetric data obtained from echosounding surveys of Sutami Reservoir conducted in 2019 and 2022. The bathymetric data used has been corrected with reservoir water level variation data (tidal data) to ensure that the bathymetric measurements accurately reflect depths relative to the reservoir's normal water level. Secondary data includes the final report on the Study and Detailed Engineering Design (DED) of the Downstream Dredging Concept for Sutami Dam, which provides information on soil material data, sediment samples, dredger inventory, and dredging routes.

**Table 1**. Summary of grain size test results BR1-BR3 (Perum Jasa Tirta I, 2022a)

| Parameter | | BR1 (6-6.5) | BR2 (4-4.5) | BR3 (4-4.5) |
|---|---|---|---|---|
| D.60 (mm) | | 0.0174 | 0.0174 | 0.0227 |
| Max size (mm) | | 2.0 | 4.75 | 2.0 |
| Grain size distribution (%) | Clay | 44.90 | 43.80 | 42,90 |
| | Silt | 39.60 | 41.80 | 38,10 |
| | Sand | 15.5 | 14.50 | 19.0 |

Soil surveys and sediment sampling were conducted in 2022 at the designated dredging locations within Sutami Reservoir. Soil parameters were analyzed in the laboratory using grain size analysis and hydrometer analysis, as presented in Table 1 and Table 2. The laboratory test results of sediment samples were used to determine the appropriate dredging method and equipment for the planned dredging locations.

**Table 2**. Summary of triaxial test results (Perum Jasa Tirta I, 2022a)

| | Parameter | BR1 (6-6.5) | BR2 (4-4.5) | BR3 (4-4.5) |
|---|---|---|---|---|
| Properties | Specific gravity | 0.0174 | 0.0174 | 0.0227 |
| | Natural water content (%) | 2.0 | 4.75 | 2.0 |
| | Wet density (g/cm$^3$) | 1.634 | 1.686 | 1.705 |
| | Dry density (g/cm$^3$) | 1.104 | 1.134 | 1.198 |
| | Saturated density (g/cm$^3$) | 1.665 | 1.703 | 1.730 |
| | Submerged density (g/cm$^3$) | 0.665 | 0.703 | 0.730 |
| | Void ratio e | 1.278 | 1.324 | 1.136 |
| | Degree of saturation (%) | 94.61 | 96.95 | 95.18 |
| Consistency | Liquid limit (%) | 87.93 | 89.54 | 82.37 |
| | Plastic limit | 38.82 | 39.03 | 37.26 |
| | Plasticity index | 49.11 | 50.51 | 45.11 |
| | Flow index | 16.65 | 18.83 | 18.60 |
| | Fine grained soil | MH | MH | MH |
| Shearing streng | Cohesion C (kg/cm$^2$) | 0.141 | 0.215 | 0.206 |
| | Internal friction φ | 11$^o$ | 11$^o$ | 12$^o$ |

### 2.2 Research Methodology

This study was conducted by considering the background issues that arise at the research location, which then led to the formulation of the problem statement. The flowchart of this study can be seen in Figure 1. Once the necessary data was obtained, the next step involved collecting primary and secondary data. Subsequently, a bathymetric data analysis was conducted by comparing the 2019 and 2022 data using ArcMap 10.8.2 and the cut-fill method. The final result of this analysis includes the calculation of potential sediment volume and the determination of dredging locations. The dredging location mapping (zoning) process is the stage in which the operational route of the dredger is established (Majid & Kurniawati, 2018).

With the determination of a wider dredging location in the reservoir inundation area, it is expected to increase the dredging volume beyond what has been done so far. The dredging activity serves as a continuous "maintenance" operation so that the sediment removed

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each year approaches the amount of sediment entering the reservoir (Randle et al., 2019). Sediment in the reservoir is extracted using a hydraulic dredger, which can achieve high production rates while handling various grain sizes, minimizing the use of large water volumes, and not disrupting reservoir operations (Morris, 2020).

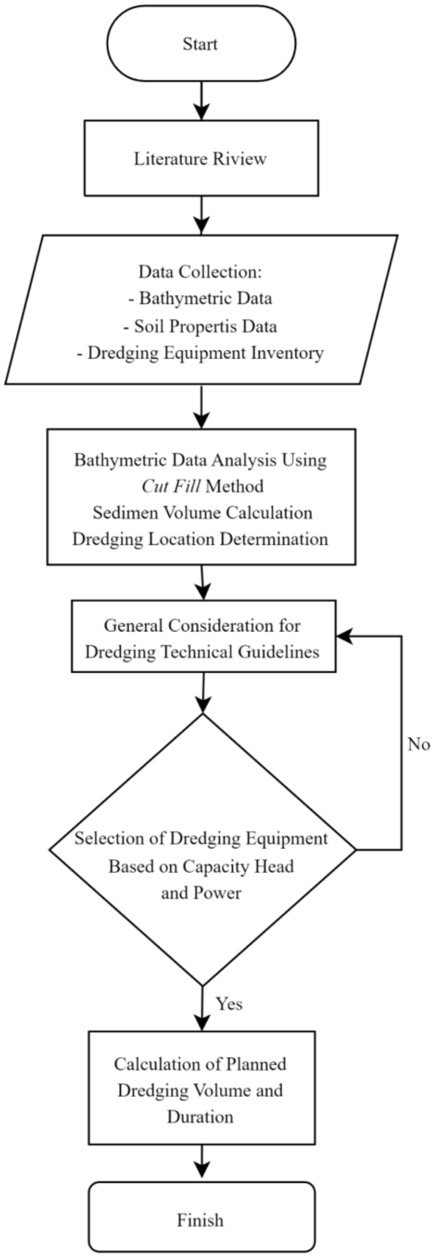


**Figure 1**. Flowchart of research on optimization of dredging location determination

Several aspects will be considered in selecting the dredger. According to the Technical Guidelines for Dredging and Reclamation Activities, the selection of dredging equipment is based on a matrix that is adjusted to field conditions and the type of material being dredged (Kementerian Perhubungan, 2017).

At the planning stage, the selection of the dredger to be used is carried out by examining the head capacity and available power. Determining the effective head of the pump begins with identifying the type of sediment to be suctioned (Khakiki et al., 2022). The selection of dredging equipment is conducted to assess the effectiveness of the dredger's capability. Determining the placement location of the dredger is crucial to enhancing the efficiency of the dredging process.

### 2.3 Pump Head Analysis

Head is the energy per unit weight that must be provided to flow a certain amount of liquid as planned, according to the pump installation conditions, or the pressure required to move a certain amount of liquid, which is generally expressed in units of length (Prasetyo H et al., 2014). The calculation of pump head includes static head, pressure head, velocity head, and head loss. Therefore, the value of static head can be determined using Equation 1.

$$\text{Hs} = h_d + h_s \tag{1}$$

where *Hs* is the static head of the pump (m), $h_d$ is the static head at the discharge side (m), $h_s$ is the static head at the suction side (m).

Pressure head is the difference between the pressure applied to the liquid surface on the suction side and the discharge side. The value of the pressure head can be calculated using Equation 2.

$$\text{Hp} = \frac{p2-p1}{pg} \tag{2}$$

where p2-p1 is the pressure difference between the inlet and outlet surfaces, $\rho$ is the fluid density (kg/m³), and $g$ is the gravitational acceleration (m/s²).

Velocity head is the difference between the fluid velocity in the discharge channel and the suction channel. The value of the velocity head can be calculated using Equation 3.

$$\text{Hv} = \frac{(V2^2-V1^2)}{2g} \tag{3}$$

where V1 is the average velocity at the suction position (m/s), V2 s the average velocity at the discharge position (m/s), and g is the gravitational acceleration (m/s2).

Major head losses refer to the head loss caused by friction between the fluid and the pipe material along the length of the pipe used (Yohana et al., 2022). The value of major head losses can be calculated using Equation 4.

$$\text{Hf}_{mayor} = f\ x\ \left(\frac{L}{D}\right) x\ \left(\frac{v^2}{2g}\right) \tag{4}$$

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where $L$ is the pipe length (m), D is the diameter used (m), $v$ is the fluid flow velocity (m/s) and $f$ is the pipe friction factor.

Minor head losses are the head losses caused by fittings and valves in the piping system. The value of minor head losses can be calculated using Equation 5.

$$\mathrm{Hi}_{minor} = k \; x \; \left(\frac{v^2}{2g}\right) \tag{5}$$

where $k$ is the energy loss coefficient depending on the type of pipe geometry change, $v$ is the fluid flow velocity (m/s), and $g$ is the gravitational acceleration (m/s²).

Pump power is influenced by the total head caused by pipe length, roughness, pipe accessories, and the maneuvering capability of the vessel (Mahendra, 2014). Total head is a condition that reduces the power generated by the pump or can be defined as the resistance to the working fluid flow. Pump power can be calculated using Equation 6.

$$P = \frac{1000 \; x \; W \; x \; Q \; x \; Ht}{75 \; x \; n} \tag{6}$$

Where $P$ is the pump power (kW), $W$ is the specific weight of the material (g/cm³), $Q$ is the flow capacity (m³/s), $Ht$ is the total head (m), and $n$ is the efficiency.

## 3.Results and Discussion

### 3.1 Existing Dredging Analysis

The sediment dredging plan at Sutami Reservoir, as outlined in the 2024 summary document, targets a planned dredging volume of approximately ±400,000 m³. The dredged sediment will be disposed of in a spoil bank using floating heavy equipment, namely the Cutter Section Dredger (CSD)/ dredger SKK-06 Dixie St-Louis 2-16 and the IHC Beaver 1200 C dredger.

Sediment management at Sutami Reservoir is carried out through reservoir dredging, with the dredged sediment placed in spoil banks located at 14 sites near the reservoir's water edge. Available data on sediment dredging at Sutami Reservoir, based on a study report by Perum Jasa Tirta I (2022) in Table 3. Indicates that the largest dredging operation was conducted in 2006.

### 3.2 Dredging Volume Potential Analysis

ArcMap 10.8.2 is one of the software programs that can be used to calculate the potential dredging volume. This program can be utilized to create contour maps and calculate cut-and-fill volumes by utilizing surface data from the top layer (bathymetry in 2022) and the bottom layer (bathymetry in 2019).

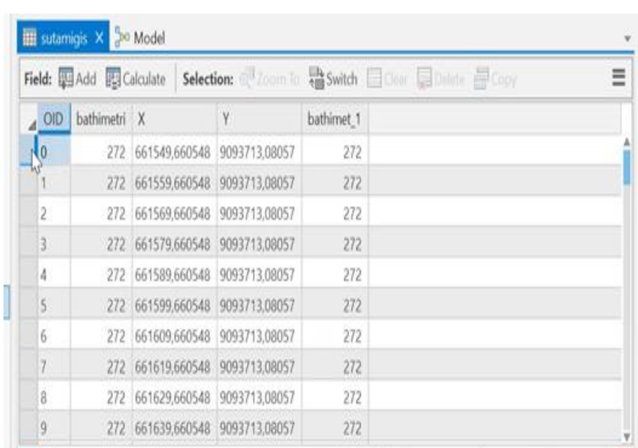
#### 3.2.1 Input Data ArcMap

To import bathymetric data into ArcMap 10.8.2, XYZ coordinate points are required. The processing of bathymetric data to obtain XYZ coordinate points is done using ArcGIS Pro with the Spatial Analyst Tools command. This command allows the export of bathymetric data in point form into the XYZ coordinate format.

**Table 3.** Historical dredging data of sutami reservoir from 2004 to 2022

| Years | Dredging volume (m$^3$) |
|---|---|
| 2004 | 138,680 |
| 2005 | 401,390 |
| 2006 | 587,273 |
| 2007 | 300,750 |
| 2008 | 303,909 |
| 2009 | 315,445 |
| 2010 | 439,694 |
| 2011 | 312,263 |
| 2012 | 410,180 |
| 2013 | 175,005 |
| 2018 | 434,000 |
| 2019 | 505,000 |
| 2020 | 434,000 |
| 2021 | 481,900 |
| 2022 | 420,000 |

The process involves selecting the raster file to be exported, then choosing the output table. Once the process is executed, opening the attribute table will display the XYZ data output (Figure 2). After obtaining the XYZ coordinate points for the designated area, the next step is to open the Add XY Data module in ArcMap.




| OID | bathimetri | X | Y | bathimet_1 |
|---|---|---|---|---|
| 0 | 272 | 661549,660548 | 9093713,08057 | 272 |
| 1 | 272 | 661559,660548 | 9093713,08057 | 272 |
| 2 | 272 | 661569,660548 | 9093713,08057 | 272 |
| 3 | 272 | 661579,660548 | 9093713,08057 | 272 |
| 4 | 272 | 661589,660548 | 9093713,08057 | 272 |
| 5 | 272 | 661599,660548 | 9093713,08057 | 272 |
| 6 | 272 | 661609,660548 | 9093713,08057 | 272 |
| 7 | 272 | 661619,660548 | 9093713,08057 | 272 |
| 8 | 272 | 661629,660548 | 9093713,08057 | 272 |
| 9 | 272 | 661639,660548 | 9093713,08057 | 272 |

**Figure 2**. XYZ data output results

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### 3.2.2 Contour Generation in ArcMap

To create a DEM file from each bathymetric dataset, the Topo to Raster command is used. The process involves inputting the 2019 bathymetric feature data as a point elevation type and setting the field to elevation (as the Z data). Additionally, the 2022 boundary file is used with the boundary type, as shown in Figure 3. This process is then repeated with the 2022 bathymetric data, resulting in a DEM output as shown in Figure 4.

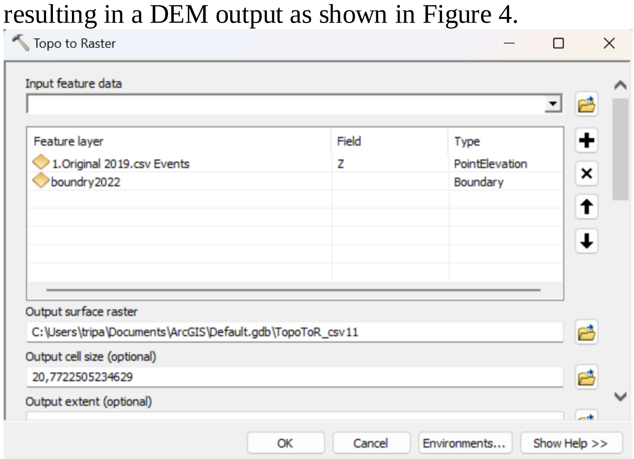



**Figure 3**. Topo to Raster command in ArcMap

### 3.2.3 Calculation Using ArcMap

Volume calculation in ArcMap is performed using the overlaying principle, which involves subtracting the lower boundary from the upper boundary. The upper boundary is based on the 2022 contour data, while the lower boundary is based on the 2019 contour data. This process is carried out using the Cut Fill command in the Raster Surface module. In the Input Before Raster Surface, the 2019 contour file is entered, and in the Input After Raster Surface, the 2022 contour file is entered, as shown in Figure 5. The output will generate a Cut-Fill map in ArcMap, as illustrated in Figure 6. The analysis results indicate that the potential sediment volume accumulation between 2019 and 2022 is 13,203,244.80 m³.

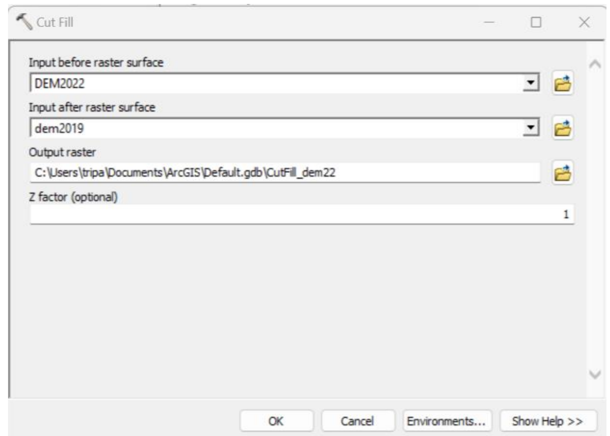



**Figure 5**. Cut Fill command in ArcMap

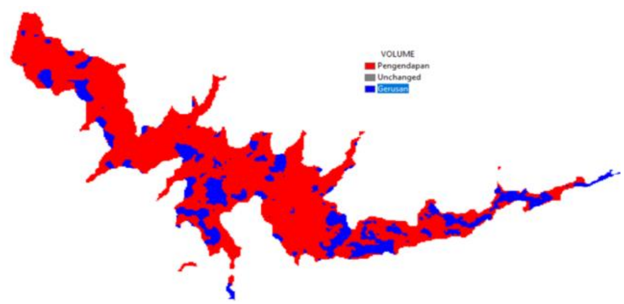
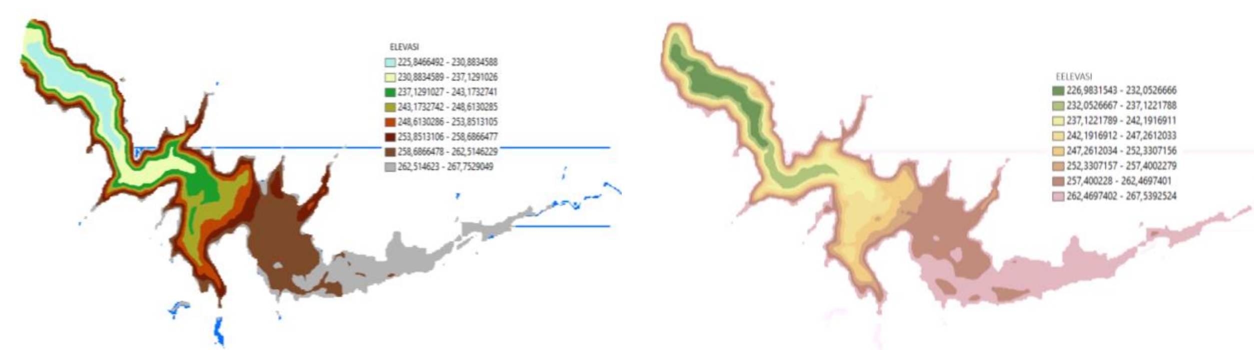



**Figure 6**. Cut Fill map results in ArcMap

## 3.3 Determination of Dredging Location

In this case study, the author divides the dredging zone into two parts: the upstream zone and the downstream zone, as shown in Figure 7. This division aims to facilitate the analysis of the dredging equipment required.



(a) (b)

**Figure 4.** Contour generation results in ArcMap. (a) Dem data 2019, (b) Dem data 2020

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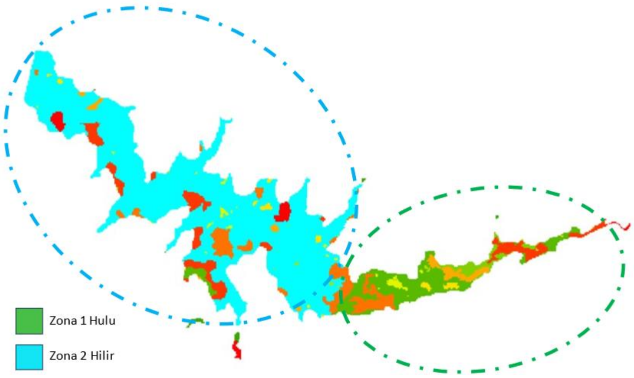


**Figure 7**. Dredging area planning zoning

The planned dredging area in Zone 1 is located in the upstream area, extending downstream for 5 km. The sediment elevation in the dredging area ranges from +260 m to +265 m, as shown in Figures 8 and 9. Therefore, the planned lowest dredging base elevation is set at +255 m. The dredger's effective depth is planned to reach 18 m, with the High Water Level (HWL) of Sutami Reservoir at an elevation of +272.50 m.

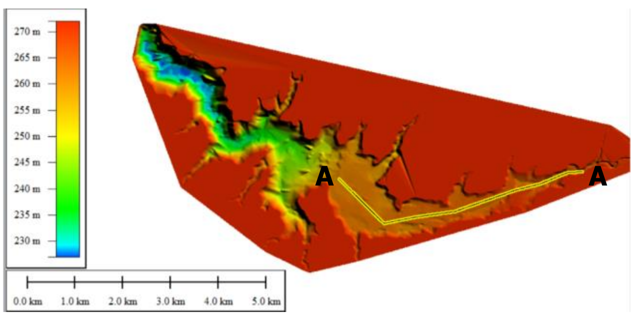


**Figure 8**. Top view of the reservoir bottom for planned dredging in zone 1

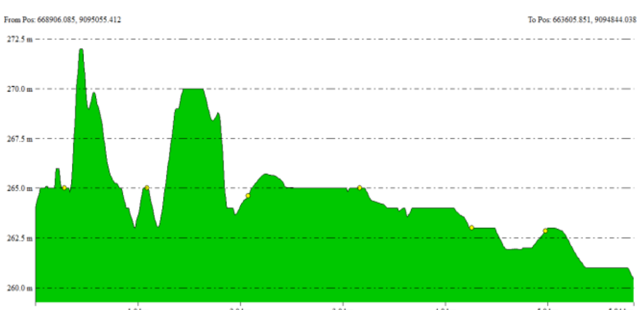


**Figure 9**. Longitudinal section of the reservoir bottom in zone 1

The planned dredging area in Zone 2 is located in the middle area, extending downstream along the shoreline, with an elevation ranging from +260 m to +270 m, as shown in Figure 10. Therefore, the planned lowest dredging base elevation is set between +260.50 m and +265 m. The dredger's effective depth is planned to reach 12 m, with the High Water Level (HWL) of Sutami Reservoir at an elevation of +272.50 m.

### 3.4 Selection of Dredger Type

In selecting the type of dredger to be used, several factors serve as parameters. These parameters are derived from the dredger selection matrix in the Technical Guidelines for Dredging of Navigation Channels and/or Port Basins, which has been adjusted for reservoir dredging, with some parameters simplified in Table 4. The parameters considered include: (1) Sediment type – Based on three tested samples, the sediment in Sutami Reservoir is predominantly silt and clay. (2) Minimum initial depth – Modeling results using ArcMap indicate that the minimum initial depth in the dredging area is 2 meters. (3) Maximum dredging depth – Modeling results using ArcMap indicate that the maximum dredging depth in the area is 15 meters.

**Table 4**. Matrix for selecting dredging equipment types

| Field Conditions | | Type Dredging Equipment | | | |
|---|---|---|---|---|---|
| | | CSD | Grab | Backhoe | Dipper |
| Type of Material | Clay | 3 | 2 | 2 | 2 |
| | Silt | 1 | 1 | 2 | 3 |
| | Sand | 1 | 2 | 2 | 3 |
| Minimum Initial Depth (m) | 2 | V | N | V | V |
| Maximum Dredging Depth (m) | 15 | V | V | V | N |
| | | 5 | X | 6 | X |

Note :1 = *suitable*; 2 = *acceptable*; 3 = *marginal*; N = *not usually suitable*; V = *mandatory*.

Based on the matrix in Table 4, the most suitable dredger is the Cutter Suction Dredger (CSD). To determine the dredger specifications that best meet the planned power requirements for Sutami Reservoir, a dredger performance analysis was conducted. In this study, the author utilized data from Julong Cutter Suction Dredgers with the following types: JLCSD300, JLCSD400, JLCSD500, and JLCSD650. Table 5 presents the specifications for each dredger type.

### 3.5 Dredger Performance Analysis

The dredger performance analysis is conducted to evaluate the power capacity of the dredger during field operations. Referring to Table 4, the type of dredger suitable for application in Sutami Reservoir is the Cutter Suction Dredger (CSD). This method falls under the suction dredger category, where sediment from the reservoir bed is suctioned and discharged through a pipeline. The suction process is carried out using a pump installed on the dredger.

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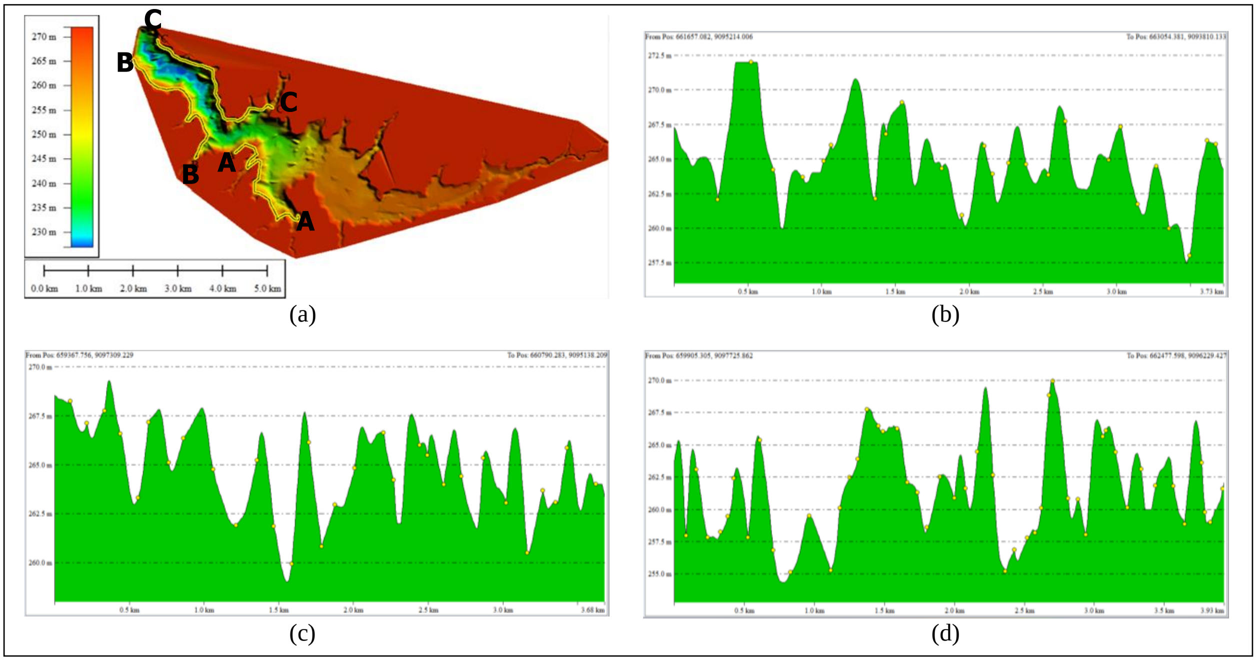

**Figure 10**. Planned dredging for zone 2. (a) Top view, (b) Longitudinal section A-A, (c) Longitudinal section B-B, (d) Longitudinal section C-C

**Table 5**. Technical specifications of cutter suction dredger (CSD)

| Data | Cutter Suction Dreger | | | |
|---|---|---|---|---|
| | JLCSD300 | JLCSD400 | JLCSD500 | JLCSD650 |
| OA Length (Ladder included) | 28m | 31m | 39m | 45.5m |
| Hull Width | 5.2m | 6.2m | 7.8m | 9.1m |
| Hull Depth | 1.6m | 1.8m | 2.0m | 2.75m |
| Flow Capacity | 1200m³/h | 2200m³/h | 3500m³/h | 5000m³/h |
| Standard Dredging Depth | 12m | 14m | 14m | 18m |
| Discharge Distance | 1000m | 1200m | 1500m | 2000m |
| Suction Pipe Diameter | 300mm | 400mm | 500mm | 650mm |
| Discharge Pipe Diameter | 300mm | 400mm | 500mm | 650mm |
| Engine Power | 619kw | 995kw | 1401kw | 2623kw |

### 3.5.1 Head Statis

In a Cutter Suction Dredger, the pump used is a centrifugal pump mounted on the vessel. The JLCSD300 dredger has a dredging depth capacity of 12 meters and a discharge height of 4 meters. Thus, the static head is calculated as follows:

*Head statis* = 12 + 4 = 16 meters

The static head values for each dredger type can be found in Table 6.

**Table 6**. Head statis values

| | JLCSD300 | JLCSD400 | JLCSD500 | JLCSD650 |
|---|---|---|---|---|
| Head Statis | 16 | 18 | 18 | 22 |

### 3.5.2 Head Pressure

In this study, the pump system operates in an open-environment condition, meaning the inlet and outlet pressures are equal, resulting in a pressure head ($Hp$) value of 0.

### 3.5.3 Head Velocity

In this study, the suction pipe diameter and discharge pipe diameter follow the same specifications as those provided by the manufacturer. As a result, the velocity at the discharge and suction sides is equal, leading to a velocity head ($Hv$) value of 0.

### 3.5.4 Head Mayor Losses

After obtaining the friction factor value for each dredger type, the major head losses can be calculated. For the JLCSD300 dredger, the major head loss calculation is as follows:

$$\mathrm{Hf}_{mayor} = 0.0111\ x\ \left(\frac{1000}{0.4}\right) x\ \left(\frac{4.713}{2x9.81}\right) = 41.903\ \mathrm{m}$$

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the major head loss values for each dredger type can be found in Table 7.

**Table 7**. Head mayor losses values

| | JLCSD300 | JLCSD400 | JLCSD500 | JLCSD650 |
|---|---|---|---|---|
| Head Mayor Losses | 41.90 | 46.97 | 43.08 | 27.45 |

### 3.5.5 Head Minor Losses

In this study, the variations used include six 90° flanged elbows, one NRV valve for the sand pump, four 90° flanged elbows, and one gate valve for the cutter suction dredger. The friction coefficient values can be found in Table 8.

**Table 8**. Friction coefficient values

| No | Item | n | k | n x k |
|---|---|---|---|---|
| 1 | Elbow Flange $90^0$ | 10 | 0.2 | 2.0 |
| 2 | NRV valve | 1 | 0.15 | 0.15 |
| 3 | Gate valve | 1 | 0.15 | 0.15 |
| | | | Total | 2.30 |

After obtaining the friction coefficient values, the minor head loss for the JLCSD300 dredger can be calculated as follows:

$$\mathrm{Hi}_{minor} = 2.3\ x\ \left(\frac{4.713}{2x9.81}\right)$$
$$= 2.605 \text{ meters}$$

thus, the minor head loss values for each dredger type can be found in Table 9.

**Table 9**. Head minor losses values

| | JLCSD300 | JLCSD400 | JLCSD500 | JLCSD650 |
|---|---|---|---|---|
| Head Minor Losses | 2.60 | 2.77 | 2.87 | 2.05 |

### 3.5.6 *Head Losses Total*

Total head losses are the sum of minor head losses and major head losses. For the JLCSD300 dredger, the total head loss can be calculated as follows:

$$Hl = 41.903 + 2.605$$
$$= 44.508 \text{ meters}$$

thus, the total head loss values for each dredger type can be found in Table 10.

**Tabel 10**. Head losses total values

| | JLCSD300 | JLCSD400 | JLCSD500 | JLCSD650 |
|---|---|---|---|---|
| Head Losses Total | 44.508 | 49.740 | 45.950 | 29.500 |

### 3.5.7 Head Total

Total head is the sum of static head ($Hs$), pressure head ($Hp$), velocity head ($Hv$), and head losses ($Hl$) on both the suction and discharge sides of the pump. For the JLCSD300 dredger, the total head can be calculated as follows:

$$Ht = Hs + Hp + Hv + Hl$$
$$= 16 + 0 + 0 + 44.508$$
$$= 60.508 \text{ meters}$$

Thus, the total head values for each dredger type can be found in Table 11.

**Tabel 11**. Head losses total values

| | JLCSD300 | JLCSD400 | JLCSD500 | JLCSD650 |
|---|---|---|---|---|
| Head Total | 60.508 | 67.740 | 63.950 | 51.500 |

### 3.5.8 Selection of Dredger Type Specifications

The selection of dredger specifications aims to determine the power required for a cutter suction dredger based on the planned parameters. The power requirement for the JLCSD300 dredger can be calculated as follows:

$$\mathrm{P}_{\mathrm{perencanaan}} = \frac{1000\ x\ 1.686\ x\ 0.333\ x\ 60.508}{75\ x\ 0.8}$$
$$= 566.76 \text{ kW}$$

Thus, the power values for each dredger type can be found in Table 12.

**Tabel 12**. Power values

| | JLCSD300 | JLCSD400 | JLCSD500 | JLCSD650 |
|---|---|---|---|---|
| Daya (kW) | 566.76 | 1,163.28 | 1,747.04 | 2,010.08 |

After obtaining the required power values, the next step is to compare the calculated power requirement with the standard power specifications provided by the manufacturer for each dredger. If the standard power of the dredger is greater than or equal to the calculated power requirement (Standard Dredger Power ≥ Planned Power), then the dredger is considered suitable for use. Table 13 presents the results of the comparison between the standard power and the planned power.

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**Table 13**. Dredging equipment's power check results

| Dredging Equipments | $P_{standard} > P_{plan}$ | Description |
|---|---|---|
| JLCSD300 | 619 ≥ 566.76 | Acceptable |
| JLCSD400 | 995 ≥ 1,163.28 | Not acceptable |
| JLCSD500 | 1401 ≥ 1,747.04 | Not acceptable |
| JLCSD650 | 2623 ≥ 2,010.08 | Acceptable |

### 3.5.9 Calculation of Dredging Work Volume

In this study, the dredging operation runs for eight working hours per day (one shift) and is conducted over three months.Each dredging cycle includes the following preparation stages, first positioning the dredger, commonly referred to as maneuvering. Second, mobilizing the sediment transport pipes from the workshop/storage location to the spoil bank. Third, assembling and disassembling HDPE/PVC and rubber pipes. These preparation activities are carried out one day before the dredging begins.

The dredging volume per cycle depends on the efficiency of the dredger. In this case study, the CSD dredger is assumed to have an efficiency of 40% with favorable weather conditions. The volume of sediment that can be dredged by the dredger is shown in Table 14.

**Table 14**. Planned dredging volume increase

| Description | Type Equipments | | Unit |
|---|---|---|---|
| | JLCSD 300 | JLCSD 650 | |
| Working Time | 8 | 8 | Jam |
| Flow Capacity | 1200 | 5000 | $m^3$/jam |
| Efficiency | 40 | 40 | % |
| Capacity /hour | 480 | 2000 | $m^3$/hour |
| Capacity /day | 3840 | 16000 | $m^3$/day |
| Capacity /month | 84.480 | 352.000 | $m^3$/month |
| Total | 436.480 | | $m^3$/month |

When combined with the existing available equipment, the dredging volume of Sutami Reservoir over one year can be seen in Table 15.

**Table 15**. Planned dredging volume per year

| Description | Existing Dredging | Additional Dredging | Unit |
|---|---|---|---|
| Capacity /year | 392,749 | 1,309,440 | $m^3$/year |
| Total | 1,702,189 | | $m^3$/year |

## 4. Conclusion

After analyzing the research problem, it was found that the dredging locations were divided into two zones: Zone 1 (upstream area) and Zone 2 (downstream area). The dredging area in Zone 1 is located in the upstream section, extending 5 km downstream, with sediment elevation ranging from +260 m to +265 m. The planned dredger depth reach is 18 m (effective dredging depth). The dredging area in Zone 2 is in the middle section, moving downstream along the shoreline, with sediment elevation ranging from +260 m to +270 m. The planned dredger depth reach is 12 m (effective dredging depth). The potential dredgable sediment in Sutami Reservoir from 2019 to 2022 is 13,203,244.80 m³. By implementing a scenario that utilizes two existing dredgers along with two additional new dredgers, the dredging capacity in Sutami Reservoir is increased by 1,702,189 m³ per year. For long-term management to maintain the reservoir's function and lifespan, gradual increases in dredging volume are necessary. Additionally, annual evaluations of sediment deposition in Sutami Reservoir should be conducted using bathymetric data analysis.

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