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# Development of Performance Index Model for Assessing the Multipurpose Reservoir Storage Capacity

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**Abstract** This research intends to assess the storage capacity performance of multi-purpose reservoir in design stage. However, the performance size of reservoir storage capacity shows the reliability in guaranteeing water demand-supply and flood control storage. The methodology consists of data collecting, data analysis, calibration of low flow and high flow model by using HEC-HMS, analysis of reservoir storage capacity by using SPA, assessment analysis to the performance index model of reservoir storage capacity for water demand-supply by using McMahon approach, preparation of model for determining the influenced variables by using SEM-PLS, regression model for developing the performance index of multi-purpose reservoir storage capacity by using GRG approach, and performance classification model of multi-purpose reservoir storage capacity by using zonation approach. The result shows that the performance index model of multi-purpose storage capacity by using the variable, indicator, and variable index weight is as follows: KT** = 0.20030 CV + 0.457672 D + 0.16677 KA + 0.175258 DF (with RMSE = 0.218483 and NSE = 0.758675). This research is hoped to predict the feasibility of reservoir storage capacity and performance of reservoir storage capacity based on the ability to fulfil water demand in various conditions of storage capacity for monthly and annual requirements. In addition, it can be a reference in assessing the performance of reservoir storage capacity and utilization so it can be used as the base for decision making to design the dimension of dam completion structure and design of reservoir management.

**Keywords** Classification Model, Design Stage, HEC-HMS, Performance of Reservoir Storage Capacity, Regression Model, SEM-PLS

## 1. Introduction

Based on a few research related to analysis of the role or function of reservoir storage capacity conducted by Granados et al. [1] for 16 watersheds in South Europe, it expressed that watershed with big storage value (K) showed that water decreasing is comparable with mean annual flow (MAF). However, watershed with small storage indicated that water decreasing is bigger than water supply from mean annual decreasing and water supply change with mean annual flow change (MAF) which showed that weakening of climate impact changed the projection of water supply [2], variability of water supply change (Cv) and mean annual flow (MAF) which showed the uncertainty decreasing of climate change projection [3] to water supply. In Indonesia, there is Circular Letter of Water Resources Directorate General 2017 about manager assessment Guidance of Dam Performance as the reference for dam manager in carrying out dam performance assessment for handling the priority of dam management. One of them is related with reservoir capacity to know and measure the effectivity of dam operation when the assessment with the variables of storage capacity (K), inflow (I), and outflow (D) is carried out.

Xia et al. [4] researched the reservoir capacity function as the flood control in Three Gorges dam in Yangtze River. However, the variables consisted of flood event, flood volume (Qf), reservoir capacity (K), water level in reservoir, lake, and downstream (h). Basu et al. [5] researched in more than 90,000 big dams that are registered in USA, and it gave the new paradigm to design and manage reservoir sustainably by using the parameters of sediment speed, reservoir capacity (K), water demand (D), reservoir utilization, design cost, construction cost, sediment management cost, operation and maintenance cost. Brunner et al. [6] carried out their research in 307 watersheds in Swiss and used the historical data in 140 watersheds and it expressed that there was spatial incompatibility between water scarcity (inflow) and storage availability (K) because water that was saved in reservoir in the southern of Alpen Mountains was often not available to be used in northern. Jing et al. [7] in China has researched in Three Gorges Reservoir. They concluded that it was important to increase reservoir safety from flood and river downstream, and to maximize the flood control as reservoir utilization by using the variable of daily mean discharge, volume of $Q_{1000}$-design flood, Cv, and Cs. Kwak [8] investigated multi-purpose dams in Han watershed that are Soyanggang, Chungju, and Hoengseong Dams to determine the method in evaluating dam operation of flood control and low flow with the variables consisted of inflow, outflow, CDF-design rainfall with various return periods, CDF-design flood with several return periods, and reservoir operation. Research of Oskoui et al. [9] was carried out in 3 rivers that were Jahor, Melaka, and Muar Rivers in Semenanjung Malaya. They developed the regression relation of SYP (Storage Yield Performance) by using variables of annual mean discharge (MAF), demand standard (m), time-based reliability ($0.9 < Re < 1$), vulnerability ($0 < Vu < 0.3$), coefficient of variance (Cv), and skewness of MAF (Sk).

McMahon et al. [10] used the parameters as follows: targeted draft (D) and annual mean inflow ($\mu$), then used monthly and annual discharge data in 729 rivers. However, there were less representative regional areas such as Center America (except Panama), equator of Center America South Middle East, and South-east Asia. This research produced the estimation of reservoir capacity. However, the hypothesis was calculated for every river by using SPA, behavior analysis, and Gould Dincer Gamma. Research of Adeloye et al. [11] was carried out in 15 rivers, however, 12 rivers for calibration and 3 rivers for validation. The rivers were in South Africa, Australia, South America, North Africa, North America, Europe, South Pacific, and the parameters consisted of Cv, D, R, $K_A$. They were successful in developing the regression model for predicting the annual capacity as well as over-year capacity for reservoir design stage.

Hanazaki et al. [12] carried out their research in 2,169 dams in Japan and America. Their research successfully integrated the reservoir flood control operation in the global flood forecast system with 4 scenarios of inflow condition or storage zone. The storage zone was intended to prevent overtopping, flood control, water supply, and water use operating for obtaining the outflow from reservoir (Q). Yannopoulus et al. [13] expressed that design of reservoir storage capacity needed low flow condition data during several years to make certain the water fulfilling for some demands. Arabzadeh et al. [14] re-designed the reservoir storage capacity without failure by using SPA method with the parameters consisting of inflow (I) and outflow (D). Vogel et al. [15] used the synthetic river flow to design the reservoir storage capacity by using the parameters of standard inflow (m), annual mean discharge (MAF, $\mu$), standard deviation ($\sigma$), variation coefficient of discharge (Cv), correction of discharge ($\rho$), faction of annual mean discharge ($\alpha$), and data length (N).

Previous research has not discussed about a time design of multi-purpose reservoir storage capacity performance by using the parameters of active storage and flood storage capacity. However, the previous research has also not made the classification design of reservoir storage capacity performance that can be used to evaluate the reservoir performance in the categories of less, enough, good, and very good performance.

## 2. Materials and Methods

### 2.1. Research Location

The research location is conducted in 16 dams that are spreading in some islands in Indonesia in which the dams consist of developed dam as well as under construction dam as well as reservoir filled stage. Figure 1 presents the plan of research location and Table 1 presents the characteristic of research location

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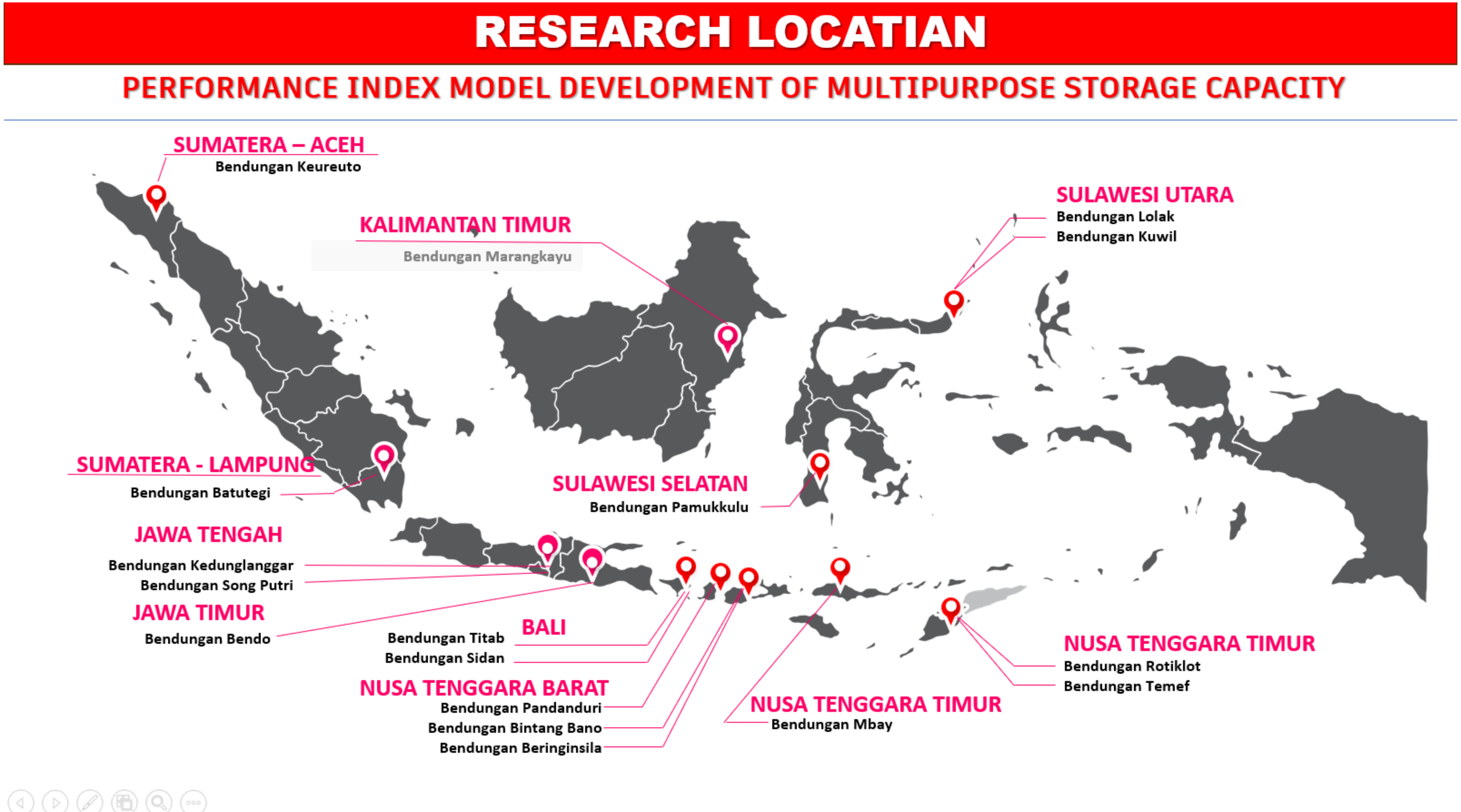



Source: own study [16]

**Figure 1.** Plan of Research Location

**Table 1.** Characteristic of Research Location

| No | Location | Island | Watershed area ($km^2$) | Depth of dam (m) | Total of volume (million $m^3$) | Yearly inflow (million $m^3$) | NWL: Surface area (ha) | HWL: Surface area (ha) | Irrigation area (ha) | Raw water (l/s) | Hydropower (MW) | Flood reduction (million $m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Beringin Sila | Sumbawa | 61.50 | 80.0 | 27.46 | 68.72 | 125.02 | 138.17 | 2.400 | 76 | 1.40 | 90.37 |
| 2 | Bintang Bano | Sumbawa | 212.00 | 72.0 | 65.84 | 237.43 | 130.00 | 153.00 | 6.696 | 555 | 9.00 | 21.13 |
| 3 | Pandanduri | Lombok | 64.51 | 42.0 | 29.69 | 75.57 | 316.21 | 330.45 | 5.168 | 50 | - | - |
| 4 | Titab | Bali | 82.90 | 77.8 | 12.80 | 137.35 | 65.74 | 81.65 | 1.795 | 35 | 1.50 | 12.79 |
| 5 | Sidan | Bali | 64.58 | 68.0 | 3.82 | 53.20 | 21.96 | 25.63 | 4.595 | 2140 | 0.65 | - |
| 6 | Rotiklot | Timor | 11.69 | 42.0 | 2.67 | 9.01 | 18.28 | 23.30 | 139 | 40 | - | - |
| 7 | Temef | Timor | 554.21 | 53.0 | 69.97 | 431.07 | 85.96 | 297.78 | 4.800 | 131 | 2.00 | - |
| 8 | Marangkayu | Kalimantan | 134.31 | 14.4 | 12.30 | 258.84 | 454.94 | 720.47 | 4.500 | 45 | 1.35 | - |
| 9 | Lolak | Sulawesi | 72.83 | 58.0 | 16.10 | 96.31 | 101.06 | 105.21 | 2.214 | 500 | 2.43 | - |
| 10 | Kuwil | Sulawesi | 426.83 | 77.0 | 23.37 | 463.76 | 142.50 | 173.50 | | 4320 | 1.30 | 146.60 |
| 11 | Pamukkulu | Sulawesi | 89.45 | 65.5 | 97.35 | 147.05 | 421.50 | 475.00 | 6.430 | 200 | 2.50 | 151.00 |
| 12 | Batutegi | Sumatera | 429.57 | 122.0 | 690.00 | 412.71 | 2.100 | 2.500 | 55.373 | 0 | 2x14 | 92.00 |
| 13 | Keureuto | Sumatera | 239.10 | 74.0 | 216.0 | 328.27 | 896.39 | 1,006.11 | 9,420 | 500 | 6.34 | 12.39 |
| 14 | Bendo | Jawa | 130.54 | 74.00 | 51.33 | 187.39 | 170.57 | 188.79 | | 370 | 1.56 | 0.30 |
| 15 | Kedunglanggar | Jawa | 102.40 | 54.0 | 28.33 | 335.00 | 116.88 | 133.59 | 948 | 450 | | |
| 16 | Songputri | Jawa | 1.77 | 25.0 | 0.51 | 4.18 | 10.08 | 10.65 | 148 | 75 | | |
| | Indonesia | Range | 1.77–554.21 | 14.4-122 | 0.51-690 | 4.18-463.76 | 10.08-2.100 | 10.65-2.500 | 139-55.373 | 40-4320 | 0.65-28 | 0.30-151 |

Source: own study [17]

### 2.2. Type of Reservoir Storage

In reservoir management, there are several types of water storage to make sure the stable water availability for year-on-year and from year to year. The three main storages are over-year storage, within-year storage, and carry-over storage [18]. The explanation and description are as follows:

1. Over-year Storage

- Over-year storage is water storage that is used for storing water surplus during wet years to be used in the next dry years. It is possible for reservoir to solve the variability of inflow between years and to make sure consistent water supply although there are years with low inflow years.
- Capacity of reservoir storage is used for storing water during wet years (more inflow than demand) and then it is used during dry years (inflow is less than demand).

2. Within-year Storage

- Within-year storage is water storage that is used for solving variation of inflow and water demand throughout the year. It is possible for reservoir to store water during the rainy season or inflow peak and then to use it during dry season or low inflow period in the same year.
- However, the reservoir fills during the rainy season and utilizes it during the dry season in a year.

3. Carry-over Storage

- Carry-over storage is water storage that is used for making sure that there are enough water supplies to face the long dry period. It is the combination of within-year storage and over-year storage in which the reservoir does not only store water for annual demand however it also stores the water surplus from year to year as the supply for facing the long drought.
- However, the reservoir maintains enough water supplies for facing the long drought period by combining the water supply from previous years.

Figure 2 presents the types of reservoir storage.

For several reservoirs, the real gap between demand and flow happens in a certain season (month) in a year; however, in the next year every year, the total of annual demand is lower than annual minimum discharge in river. The reservoir storage like that is known as within-year storage [19] and the reservoir storage that is prepared is only enough for fulfilling the deficiency of seasonal inflow. The reservoir will have a critical period (CP) of less than 12 months and therefore the emptying cycle of reservoir will happen. The analysis can be simplified by identifying the critical twelve months and the storage result design is based on the critical twelve months. On the other side, the storage that is prepared in a reservoir may be like that so it can take place from one year to the next year, therefore it causes the inflow deficiency during several years. The system like that is said as over-year reservoir storage capacity. This will have a critical period of more than 12 months and can be analyzed effectively by using annual river discharge in the reservoir location.

### 2.3. Methodology

The procedure of this research is to develop the performance index model of reservoir storage capacity in which the steps are as follows:

1. To evaluate previous study about performance of reservoir storage capacity (Mc Mahon), $K_T$ with 3 variables: Cv, D, $K_A$.
2. To add the new variable: Df for flood storage capacity.
3. To identify the return period of flood.
4. To determine the return period of flood.
5. To analyze the capacity performance of multi-purpose reservoir storage capacity without failure ($K_T^{**}$).
6. To analyze supply storage of multi-purpose reservoir ($K_A^{**}$).
7. To analyze the regression of multi-purpose reservoir storage capacity without failure.

Figure 3 presents the flow chart of research and Figure 4 presents the detailed flow chart of research.

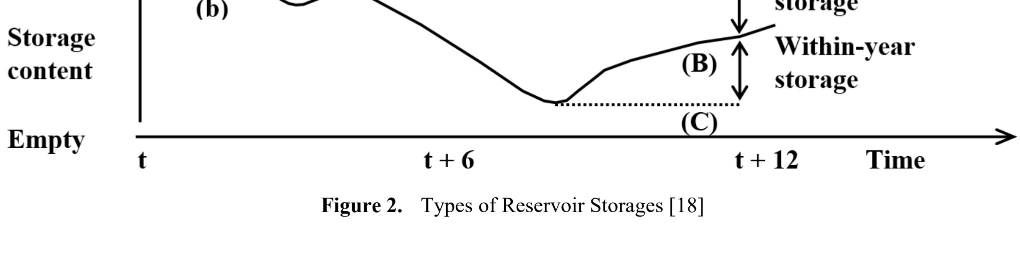
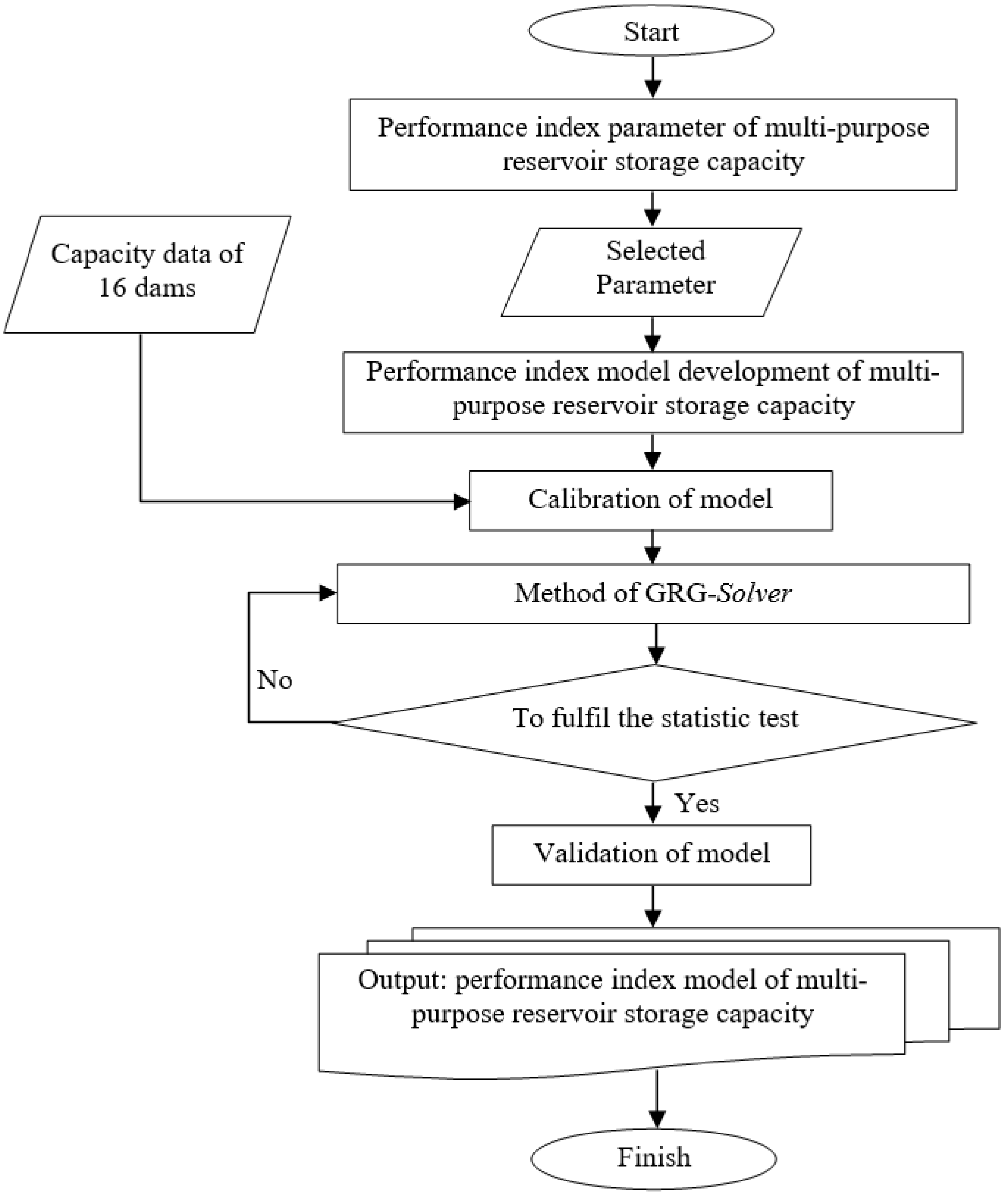
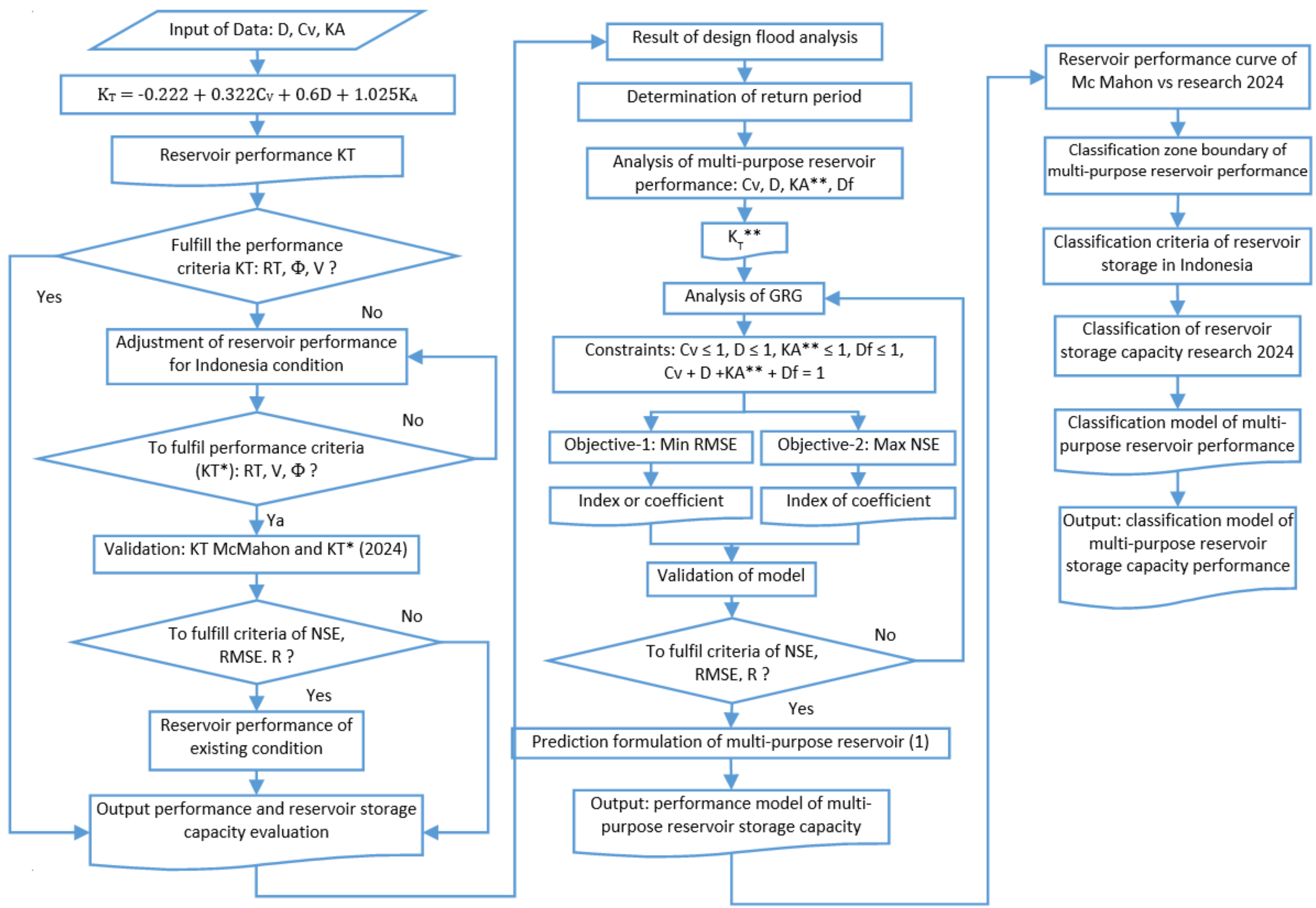



**Figure 2.** Types of Reservoir Storages [18]




Source: own study

**Figure 3.** Flow Chart of Research




Source: own study

**Figure 4.** Detailed Flow Chart of Research

## 3. Results and Discussion

In this research, the data consists of discharge variation coefficient ($C_V$), recommendation storage capacity ($K_A$), water demand (D), and flood storage capacity ($D_f$). Every variable is measured by using relevant indicator; however, the validity and reliability have been tested.

This model is in accordance with the previous research that discussed about the variability of discharge coefficient ($C_V$), water supply (D), recommendation water saving for long dry period ($K_A$) in the context of reservoir performance which Adeloye et al. 11] have researched in 15 rivers in South Africa, Australia, South America, North Africa, Asia, North America, Europe, and South Pacific, which is 12 rivers for calibration and the other 3 rivers for validation. The results show that the difference between $K_T$ and $K_A$ is within-year capacity although it is not directly seen, the systems with low $C_V$ tend to be dominated by the within-year behavior (K) mainly the low demand ratio. However, the systems with high $C_V$ tend to be dominated by over-year behavior ($K_A$). Oskoui et al. [9] have researched 3 rivers that are Jahor River, Melaka River, and Muar River in Semenanjung Malaya. The results show that storage capacity is influenced by variation coefficient of MAF ($C_V$), standard demand parameter (D), skewness ($S_k$), time-based reliability value (Re), and vulnerability value ($V_u$).

### 3.1. Capacity Performance of Multi-purpose Reservoir Storage without Failure

The need of reservoir storage for flood is notified as $D_f$. The value of $C_V$ and D is the same as the capacity performance of reservoir storage without failure for water supply. The value of $K_A$** and $K_T$** is obtained based on the SPA simulation. Table 2 shows the research result of the capacity performance of multi-purpose reservoir storage without failure. The capacity performance of multi-purpose reservoir storage without failure has a higher value than $K_T$.

Based on the 16 dams above, there is found that minimal performance of multi-purpose reservoir is about 31% and the average of reservoir performance is about 70.4%. This research is still in accordance with the previous research of Zhou et al. [19] which has classified the reservoir storage for $K_T \leq 0.3$ and $K_T > 0.3$.

**Table 2.** Performance of Reservoir Storage Capacity without Failure

| No | Location | Island | MA0F | $C_V$ | Ratio of D | Ratio of $D_f$ | Ratio of $K_A$** | Ratio of $K_T$** |
|---|---|---|---|---|---|---|---|---|
| 1 | Beringin Sila | Sumbawa | 61.41 | 0.150 | 1.0 | 0.06 | 0.23 | 0.78 |
| 2 | Bintang Bano | Sumbawa | 234.43 | 0.159 | 1.0 | 0.11 | 0.20 | 0.65 |
| 3 | Pandanduri | Lombok | 85.06 | 0.192 | 1.0 | 0.06 | 0.17 | 0.69 |
| 4 | Titab | Bali | 137.94 | 0.148 | 1.0 | 0.06 | 0.05 | 0.54 |
| 5 | Sidan | Bali | 28.78 | 0.095 | 1.0 | 0.06 | 0.12 | 0.31 |
| 6 | Rotiklot | Timor | 9.01 | 0.454 | 1.0 | 0.11 | 0.39 | 1.28 |
| 7 | Temef | Timor | 426.23 | 0.161 | 1.0 | 0.07 | 0.20 | 0.65 |
| 8 | Marangkayu | Kalimantan | 254.14 | 0.151 | 1.0 | 0.06 | 0.06 | 0.71 |
| 9 | Lolak | Sulawesi | 67.53 | 0.165 | 1.0 | 0.06 | 0.06 | 0.57 |
| 10 | Kuwil | Sulawesi | 463.76 | 0.218 | 1.0 | 0.11 | 0.22 | 0.78 |
| 11 | Pamukkulu | Sulawesi | 191.32 | 0.213 | 1.0 | 0.06 | 0.04 | 0.73 |
| 12 | Batutegi | Sumatera | 412.71 | 0.235 | 1.0 | 0.06 | 0.17 | 0.87 |
| 13 | Keureuto | Sumatera | 328.37 | 0.221 | 1.0 | 0.06 | 0.09 | 0.95 |
| 14 | Bendo | Jawa | 187.52 | 0.281 | 1.0 | 0.12 | 0.02 | 0.61 |
| 15 | Kedunglanggar | Jawa | 335.24 | 0.170 | 1.0 | 0.12 | 0.16 | 0.56 |
| 16 | Songputri | Jawa | 4.18 | 0.153 | 1.0 | 0.13 | 0.03 | 0.59 |
| Range for Indoensia | | | 4.18-463.8 | 0.095-0.454 | 1.0 | 0.062-0.125 | 0.02-0.39 | 0.31-1.28 |
| Average | | | | | | | | 0.704 |

Source: own study

### 3.2. Regression of Multi-purpose Reservoir Storage Capacity without Failure

The analysis result of reservoir storage capacity performance without failure is as the input of GRG analysis to obtain the index value and coefficient of each variable and indicator. Constraint that is used as solver is constant of each variable that is less or equal to one. Objective function is to minimize the RMSE value or to maximize the NSE value. However, the iteration result by using solver produces the prediction formulation of the performance index of multi-purpose reservoir storage capacity without failure by minimizing the RMSE value as follow:

$$KT^{**} = 0.200306\ CV + 0.457672\ D + 0.16677\ KA + 0.175258\ DF \quad (1)$$

The RMSE value for model validation is 0.218483 (minimum). It shows that the model has high accuracy. The value of NSE for model validation is 0.758675 (maximal). It shows that models can be very good interpreted. However, the iteration result by using solver produces the prediction formulation of the performance index of multi-purpose reservoir storage capacity without failure by maximizing the NSE value as follow:

$$KT^{**} = 0.19837\ CV + 0.45171\ D + 0.17299\ KA + 0.17692\ DF \quad (2)$$

The RMSE value for model validation is 0.219975 (minimum). It shows that the model has high accuracy. The NSE for validation model is 0.79003 (maximum). It shows that the model can be very good interpreted.

The equation-1 is determined as the prediction formulation of multi-purpose reservoir storage capacity without failure because it minimizes the RMSE value, and the prediction measurement of a model is as the estimation of the observed value. However, equation-2 maximizes the NSE value for calibrating the model and it cannot stand alone, and it is needed to review the other value like RMSE, P Bias, etc. The equation-1 is used in the initial stage of design or feasibility study (FS) to determine the optimum reservoir storage capacity without failure.

The prediction formulation of the performance index of multi-purpose reservoir storage capacity without failure shows that every variable has certain weight in the formula that shows the contribution level to the overall system of performance. This weight determines how important every variable is in influencing the overall performance.

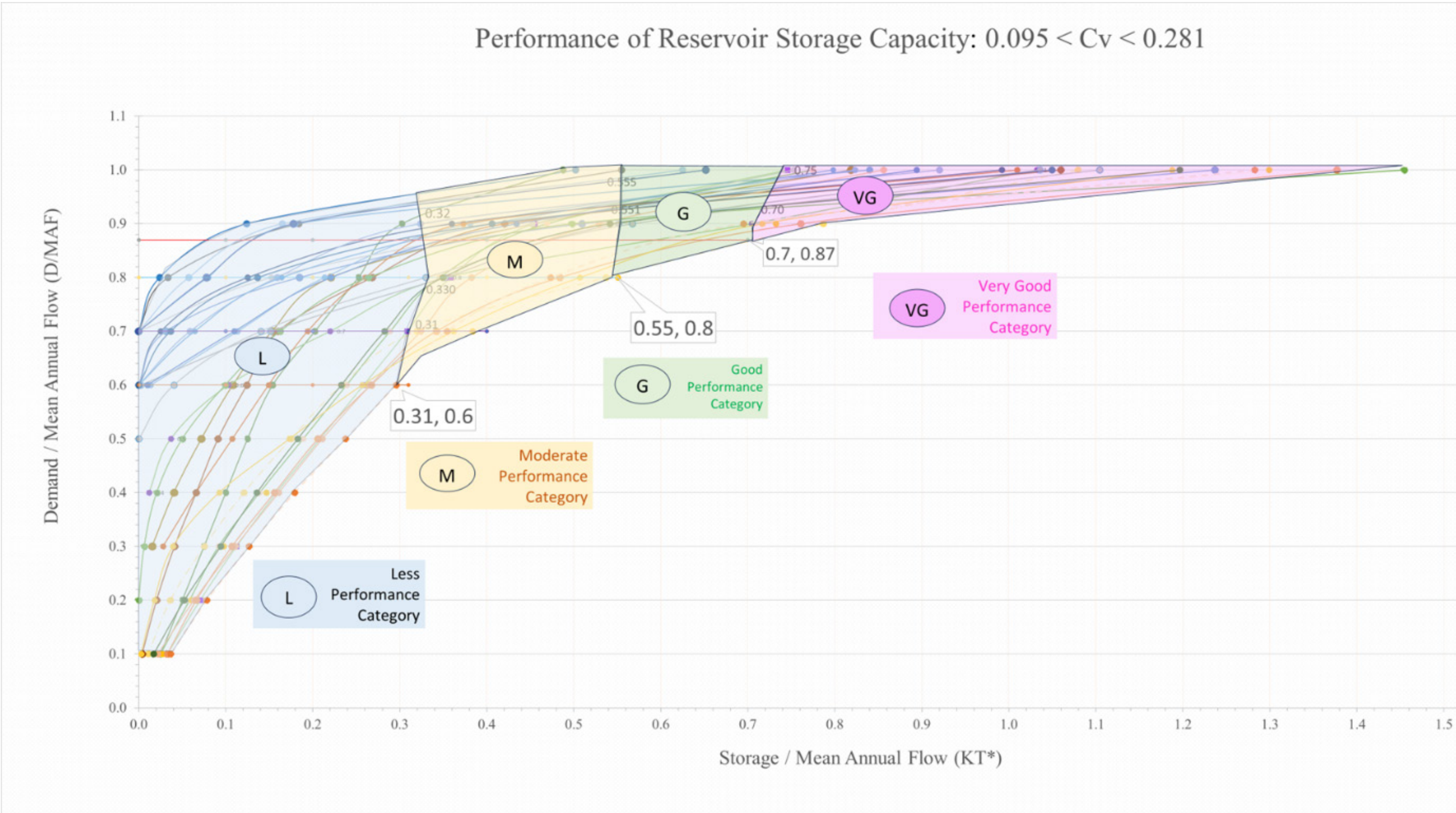
When developing this formulation, it is estimated that the contribution of each factor to the overall performance system is linear. It means that the increasing or decreasing of a unit in variable will produce a certain increase or decrease in overall performance system. This formulation has been developed through testing and empirical analysis or relevant components. Data that is obtained from this testing can be used to determine the accurate weight for every variable. When using this formulation, it can estimate the overall performance of a multi-purpose reservoir based on the variables value that are given. This can help in design, development, and evaluation of the performance index of multi-purpose reservoir storage capacity by analyzing some influenced factors.

### 3.3. Validation of Model

Validation of model uses the empirical data of 16 dams to make sure that the developed model is accurate and can be reliable. The result of $KT^{**}$ model is compared with the real performance for testing the model validation. The model validation is carried out by using the formulations-1 and 2.

The model validation for formulation-1 shows that the performance is very good, and the model is accurate so it can be reliable due to the value of RMSE is 0.249, MSE is 0.062, NSE is 0.986, and correlation is 0.80. However, the model validation for formulation-2 shows that the performance is very good, and the model is accurate so it can be reliable due to the value of RMSE is 0.253, MSE is 0.064, NSE is 0.986, and correlation is 0.80.

This model is in accordance with the previous research by Adeloye et al. [18] that discussed the variability of discharge, water supply, water storage for long drought, and flood control in the context of reservoir performance. The research of Adeloye et al. [18] was conducted in 15 rivers in South Africa, Australia, South America, North Africa, Asia, North America, Europe, South Pacific that are 12 rivers for calibration and 3 rivers for validation. The previous research found that the difference between $K_T$ and $K_A$ is capacity in year (K), however, this is indirectly seen and system with low $C_V$ tends to be dominated by the behavior in year (K) mainly low demand ratio, however, system with high $C_V$ tends to be dominated by the behavior over-year ($K_A$). The research of Oskoui et al. [9] is conducted in 3 rivers that are Jahor River, Melaka River, and Muar River in Semenanjung Malaya which is found that the storage capacity is influenced by variance coefficient of MAS ($C_V$), parameter of demand standard (D), skewness (Sk), time-based reliability (Re), and vulnerability (Vu).




Source: research of 16 dams di Indonesia, 2024

**Figure 5.** Performance Classification of Reservoir Storage Capacity for 0.095< Cv <0.281

### 3.4. Classification of Reservoir Storage Capacity of Research-2024

The classification of storage capacity performance is very important to be reviewed from some aspects as follows:

1. Analysis of performance: this classification helps to evaluate how good the reservoir storage capacity can fulfill the water demand that varies from time to time in short term as well as long term.
2. Management of water resources: this information is important in managing water resources to make sure that the stable water supply is stable and in accordance with some demands.
3. Design of infrastructure: this classification is also important in infrastructure design to build suitable reservoirs for a sustainable future.

By using this classification above, the manager of water resources can make a better decision to design and manage the reservoir capacity for fulfilling water demand efficiently and effectively. The classification model of reservoir storage capacity performance is presented in Figure 5 for $C_V < 0.281$ and the criteria are as follows:

a) $K_T \leq 0.31$, $C_V < 0.281$, $D < 0.6$, within year, less performance category
b) $K_T \leq 0.31$, $C_V < 0.281$, $D > 0.7$, within year, less performance category
c) $0.31 < K_T < 0.54$, $C_V < 0.281$, $D > 0.6$, Carry-over, moderate performance category
d) $0.54 < K_T < 0.70$, $C_V < 0.281$, $D > 0.8$, Carry-over, good performance category
e) $K_T > 0.70$, $C_V < 0.281$, $D > 0.87$, Over-year, very good performance category.

The pattern of the outflow-ratio curve (Figure 5) is sharply increasing in the beginning then it tends to be horizontal along the increasing of storage capacity ratio. The interpretation of the significantly increasing change is from all of curve segments such as when $K_T$ is less than 0.3 ($K_T \leq 0.3$) by reservoir has the within-year behavior, the more increasing change is for $C_V < 0.4$. However, for $K_T \geq 0.3$, the D is more horizontal and the monthly and annual based is getting tighter. This pattern is used to arrange the boundary and criteria of classification for the multi-purpose reservoir storage.

- **The Boundary of the Classification of Multi-purpose Reservoir Storage Capacity**

The classification model of reservoir storage capacity performance uses the zonation method with two axis that are ratio of reservoir performance (KT**) and ratio of water supply storage (D). Based on the research of 16 dams, the classification boundary that is customized with the characteristic of Indonesian region is found as follow:

a. The boundary of KT**:
   - KT** ≤ 0.31 based on the minimum KT** with Cv = 0.095
   - 0.31 ≤ KT** ≤ 0.54 based on the minimum KT** with Cv ≥ 0.1
   - 0.54 ≤ KT** ≤ 0.70 based on the average of KT** with Cv < 0.281
   - KT** ≥ 0.70

b. The boundary of D based on the curve is found that:
   - initial D for various Cv is in D < 0.6 and D > 0.7
   - D ≤ 0.60 based on the minimum KT** with Cv = 0.095
   - D ≥ 0.60 based on the minimum KT** with Cv ≥ 0.1
   - D ≥ 0.80 based on the average of KT** with Cv < 0.281

This classification boundary is in accordance with the research of Zhou et al. [19] for the classification of annual reservoir if $K_T \leq 0.30$. According to Adeloye and Montaseri [18], the reservoir classification is based on the parameter of $C_V < 0.4$ and $C_V > 0.6$, and D with the category: $D < 0.4$, $D > 0.6$ and whatever of D.

- Classification Criteria of Reservoir Storage Capacity

a. X-axis represents the storage performance index ($K_T$**) that is divided into 3 zones:
   - ✓ $K_T < 0.31$: the behavior boundary of within-year reservoir capacity along the spill out that is determined that the performance is not good.
   - ✓ $0.31 < K_T < 0.54$: the behavior boundary of carry-over reservoir capacity that is determined that the performance is good enough.
   - ✓ $0.51 < K_T < 0.70$: the behavior boundary of carry-over reservoir capacity that is determined that the performance is good
   - ✓ $K_T = 0.70$: the behavior boundary of carry-over reservoir capacity that is the water supply is very adequate and there is space for flood storage and the performance is very good.

b. Y-axis represents the ratio of water supply storage (D) and Cv < 0.4 and it is divided into 4 zones:
   - ✓ **D < 0.6:** the effective storage ($K_T$) can fulfil most of water demand (D) but not at all, it can be said that the performance is not good.
   - ✓ **0.6 < D < 0.7:** the effective storage (KT) can fulfil water supply (D) but it is not good for long dry period and it can be said the reservoir performance is good enough.

- ✓ **D > 0.7:** the effective storage (KT) can fulfil almost all of water demand (D), and it can be said that the reservoir performance is good.
- ✓ **D ~ 1:** the effective storage (KT) can fulfil all of water (D) and has enough recommendation, and it can be said that the reservoir performance is good until very good.

There are stages in implementing the research model of reservoir performance index and performance classification model of reservoir storage capacity by using zonation method so it can be clearly and systematically described, and facilitate the understanding, application, and reservoir management.

However, the stages of using this research result are as follows:

1) To collect the hydrology data that consists of
   a. Data of inflow volume in annual average (MAF million $m^3$)
   b. Data of discharge variation coefficient with the range: $0.095 < Cv < 0.4$
   c. Data of water demand, with the range: $0.6 \leq D \leq 1$ from MAF
   d. Data of enough recommendation capacity for long dry period with the range: $K_A = 2\% \sim 110\%$ from MAF
   e. Data of flood volume with certain return period, with the range: 5% ~ 35% from MAF)
2) To analyze the performance of multi-purpose reservoir storage capacity ($K_T$**) by using equation-1.
3) To plot the point result (2) into curve of reservoir storage capacity performance in accordance with the value of Cv to Figure 5.

# 4. Conclusions

Based on the analysis and discussion above, it can be concluded as follows:

The performance index model development of multi-purpose reservoir storage capacity in the design stage by using coefficient of variable, indicator, and weight of variable index is formulated as follow:

$$K_T^{**} = 0.20030\, C_V + 0.457672\, D + 0.16677\, K_A + 0.175258\, D_F \text{ (RMSE=0.218483, NSE=0.758675)}$$

The RMSE value is 0.21843, which indicates that the model has high accuracy and the NSE value is 0.758675, which indicates that the model can be good interpreted. The category of performance classification model consists of less, moderate, good, and very good. The classification is carried out to evaluate the reservoir performance in fulfilling water demand more specifically by considering discharge fluctuation and water demand during several months in one-year modification curves based on the variation coefficient of discharge ($C_V$) from 0.095 until 0.281.

The classification model of reservoir storage capacity in the graphic form is due to the criteria as follows:

a. $K_T \leq 0.31$, $C_V < 0.281$, $D < 0.6$, within-year, less performance category
b. $K_T \leq 0.31$, $C_V < 0.281$, $D > 0.7$, within-year, less performance category
c. $0.31 < K_T < 0.54$, $C_V < 0.281$, $D > 0.6$: carry-over, moderate performance category
d. $0.54 < K_T < 0.70$, $C_V < 0.281$, $D > 0.8$, carry-over, good performance category
e. $K_T > 0.70$, $C_V < 0.281$, $D > 0.87$, over-year, very good performance category.

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