Optimization of Logung Reservoir Performance

by Suharyanto Suharyanto

Optimization of Logung Reservoir Performance

F F S Jamil[1*, 3], S Darsono[2] and Suharyanto[2]

1. Introduction

Increasing the welfare and quality of life of the community is the main program of each Government by developing the potentials in the regency area. One of them is the construction of the Logung Reservoir in Kudus District, which will later be able to function as a provider of water for irrigation and raw water. With the presence of Logung Reservoir, the regency will be able to meet the water needs of the Logung Irrigation Area of 2.805 Ha and raw water of 200 liters/second [1]. The Logung Reservoir construction has completed and is ready to be impounded and operated. However, the guidelines for operating reservoirs are still in the planning stage. The existence of this research is expected to be able to provide input in the preparation of the pattern for operation of Logung Reservoir to the BBWS Pemali Juana as the manager.

The Implicitly Stochastic Dynamic Programming method is one of the optimization techniques for operating reservoirs with the aim of obtaining a reservoir operation which is assumed to be more optimal, more effective, more elastic, more economical and more reliable [2]. The Implicitly Stochastic

DP was chosen because it can summarize the goals and constraints that are non-linear in nature and can also solve a difficult problem into a collection of sub-problems [3].

1.1. Problem Formulation
In carrying out the operation of the reservoir, an operational guideline was needed to maximize the use of reservoir water. This study analyzed and formulated the operating guidelines for Logung Reservoir through the most optimal release formula using the Implicitly Stochastic Dynamic Programming optimization method to meet the water needs of the Logung Irrigation Area of 2.805 Ha and raw water requirements of 200 liters/second for Dawe and Jekulo District communities.

1.2. Purpose and objective
The purpose of this study is to optimize the function of the Logung Reservoir using guidelines for reservoir operation through the most optimal release formula with the Implicitly Stochastic Dynamic Programming optimization method. While the objectives of this study are:
1. Formulate the most optimal release formula for reservoir operations using the Implicitly Stochastic Dynamic Programming optimization method.
2. Simulates the most optimal release formula results from optimization modelling.
3. Analyze reservoir performance based on the results of simulation modelling.

1.3. Literature View

1.3.1 Optimization
Optimization is often used to solve problems that are closely related to water resources infrastructure due to limitations and constraints that allow the water resources to be utilized less optimally. There are some previous studies used optimization. This study used some of them as references. These study were conducted by [4, 5, 6, 7, 8, 9, 10, 11]. Optimization of reservoir operations can be solved by several methods. The methods are Linear Programming, Non Linear Programming, Dynamic Programming [2]. The choice of optimization modelling method depends on the characteristics of the reservoir, the availability of data, targets, and the constraints of face.

1.3.2 Dynamic Programming
Dynamic programming optimizes a concatenated decision-making process by providing a set of decisions that are interrelated with one another, which is a function of place and time. Compared to other optimization techniques, dynamic programs have a number of advantages in their use to optimize the utilization of water resources. Dynamic Programming method can summarize the goals and constraints that are non-linear, thus can solve a difficult problem into a collection of sub-problems. Solving problems with the Dynamic Programming method can be solved by moving forward or by moving backward stage by stage. Several terms and variables that exist in solving problems with the Dynamic Programming method are discretization of reservoir storage, stage, state, decision variable, objective function, constraint function, and state transformation [12]. CSUDP (Colorado State University Dynamic Programming) is one software that can be used for optimization research using the Dynamic Programming method. In research on reservoir performance optimization using CSUDP, it can be used to find the most optimal release. CSUDP was developed by Prof. John Labadie from Colorado State University, United States. Data input in this application is in the form of programming language.

1.3.3 Implicitly Stochastic Dynamic Programming
The Implicitly Stochastic DP method is a combination of Dynamic Programming optimization modelling with multi linear regression analysis to get the most optimal release formula by taking into account the storage and stochastic properties of the inflow in the previous period [13, 14]. The main objective form Dynamic programming is to get the most optimal reservoir release by using data input from the generated discharge inflow. The resulting output is in the form of release, then analyzed by the

IOP Conf. Series: Earth and Environmental Science **328** (2019) 012017 doi:10.1088/1755-1315/328/1/012017

equation of the relationship between elevation and reservoir reservoir to get the reservoir volume in each period until the end of the planned operating period. The multi linear regression, data input used is in the form of release of reservoirs at a certain period, inflow of reservoir discharge and reservoir reservoir volume in the previous period. The resulting output is the most optimal release formula. In the use of the Implicitly Stochastic Dynamic Programming method, the regression test with the help of SPSS software was carried out to obtain the most optimal release formula which was influenced by reservoir storage and reservoir inflow in the previous period.

Multi linear regression is a statistical technique that is used to study the functional relationship of one or several independent variables (variables that influence) on one non-independent variable (the variable that is affected). Multi linear regression is also defined as a study of the relationship of one variable which is able to be explained by one or more variables [15]. The first variable is the dependent variable and the second variable is the independent variable. If there are more than one independent variable, the regression analysis is called multiple linear regression analysis, because the influence of several independent variables will be imposed on the dependent variable. Multiple linear regression is used to measure the influence of more than one independent variable on non-free change.

1.4 Simulation
Simulation is a quantitative method that describes the behavior of a system from a system input that serves to estimate the system output from predetermined inputs. Simulation methods can be used to review failures produced by the output of a model in optimization in order to be closer to existing natural phenomena [16]. The simulation modelling process in the operation of reservoirs can be done with the availability of inflow data, water requirements, losses with the limitation of reservoir reservoir capacity. So that the reservoir is expected to operate throughout the year. Simulation modelling of reservoir operations is carried out by applying the reservoir balance formula. So, from the results of the simulation output it can be seen whether the available inflow discharge and reservoir capacity are able to meet the targeted needs.

1.5 Reservoir Performance
The performance of the reservoir operation is an indicator of the reservoir in operation to meet needs. Some indicators to assess the size of reservoir operations include reliability, resilience and vulnerability.

1.5.1 Reliability
Reliability is an indicator of how often the reservoir meets the targeted needs during its operation. For the operation of the reservoir there are at least two types of reliability definitions, namely [17]:
1. Percentage of conditions in which the reservoir is able to meet the needs. Often times, the definition of reliability can be associated with failure. In this case, the reservoir is considered a failure if the reservoir cannot meet the total needs.
2. The average percentage of reservoir release compared to the needs. In this definition, even though reservoir suppletion cannot meet the total needs, the whole reservoir is not considered a total failure. But it is considered that the reservoir can only supply part of the total needs.

1.5.2 Resilience
The resilience indicator was used to measure the reservoir's ability to return to satisfactory state from failure. The faster the reservoir returns to satisfactory state, the more resilient reservoir is, which means the consequences of failure are also smaller. This is assumed by using the definition of the first failure and, the calculation of the transition period from a failed state to a satisfactory state.

In the long run, the average value will show the average number of reservoir transitions from a failed state to a satisfactory state. The average duration of a reservoir in a state of continuous failure is the total amount of time the reservoir failed, to be divided by the average frequency of the reservoir transition using mathematical formula. The longer the average period of the reservoir in a state of failure, the smaller the resilience. So, the consequences of these failures will also be large.

1.5.3 Vulnerability
Vulnerability is the magnitude of failure derived from the difference between reservoir capacity and the amount of water needed, divided by the amount of water needs [18]. In this case if a failure occurs, it can be measured how much a failure occurred. In this study, vulnerability is defined as the value of the lack of discharged water from the needs.

2. Methods

2.1 Reservoir Optimization
This research used Implicitly Stochastic Dynamic Programming method. Implicitly Stochastic Dynamic Programming is an optimization concept with the Dynamic Programming method followed by Linear Multi Regression Analysis. The output of optimal reservoir release obtained from Dynamic Programming was then analyzed by Multi Linear Regression by taking into account the reservoir volume and inflow in the previous period.

2.2 Reservoir Simulation
Reservoir simulation in this study used the help of Microsoft Excel. The release formula of the results of optimization using the Implicitly Stochastic Dynamic Programming method was applied to simulation of reservoirs in each period. Conditions for reservoir water level fluctuations and long-term reservoir storage volumes that are operated will be clearly visible, according to the limits of the water release volume from the prescribed reservoir.

2.3 Reservoir Performance
The final stage of this research was reservoir performance. The performance of the reservoir operation is the main indicator whether the reservoir in its operation has meet the needs. The analysis includes reliability, resilience and vulnerability.

2.4 Research Data
Secondary data in this study were obtained from relevant agencies. The data includes:
1. Rainfall data from the rain post around the Logung watershed, namely the Rahtawu Rainfall Station, Gembong and Tanjungrejo from 2011-2017.
2. Logung River discharge data from 2011-2014.
3. Data on cropping pattern was obtained from the Logung Irrigation Area Development Research Report issued by BBWS Pemali Juana.
4. Technical Data of Logung Reservoir was obtained from the certification data of Logung Dam by BBWS Pemali Juana 2015.
5. Climatology data such as air temperature, relative humidity, wind speed, solar radiation and evaporation.

2.5 Stage of Analysis
In general research included several activities and stages, including:
1. Analysis of optimization modelling with the Implicitly Stochastic Dynamic Programming method.
2. Analysis of simulation of reservoir operations.
3. Analysis of reservoir performance.

3. Result and Discussions

3.1 Optimization Modelling Analysis
The optimization modelling analysis in this study used the Implicitly Stochastic DP Method. The results of the Implicitly Stochastic DP method in the form of reservoir water release formula were analyzed

from the results of optimization using the Dynamic Programming method using CSUDP, where it was then followed by multi linear regression analysis using SPSS software.

3.1.1 Dynamic Programming Optimization Analysis with CSUDP

Dynamic programming optimization analysis with CSUDP used inflow discharge as the main data input. Inflow discharge that was used for 25 years is based on the results of the discharge generated from 2011-2017 that have been analyzed previously. Optimization using the Dynamic Programming with CSUDP used several input data summarized in the model formulation as :

1. Objective function : $$\text{Min } Z = \sum_{i:1}^{N} \frac{|T_i - U_i|}{T_i} \quad (1)$$
2. Constraint function
   Storage constraint : $6{,}43 \text{ million m}^3 \leq X_i \leq 20{,}15 \text{ million m}^3$
   Release constraint : $0 \leq U_i \leq 3{,}89 \text{ million m}^3$
3. State transformation : $X_{i+1} = X_i + I_i - E_i - U_i - S_i$
4. Recursive equation : $$F_i(X_i) = \min\left[f_i(X_i, U_i) + F_{i+1}(X_{i+1})\right] \quad (2)$$
5. Demand : Target of water needs
6. Inflow : Generating discharge 25 years
7. Evaporation : $$Ei = e_i \times \left[\left(4{,}7898 \times \left(\frac{x_{in} + x_{out}}{2}\right)\right) + 29{,}822\right] \quad (3)$$
8. Discretization
   State variable : $\Delta X = 0{,}137 \text{ million m}^3$; Total discretization = 100
   Decision variable : $\Delta U = 0{,}100 \text{ million m}^3$

The output produced form CSUDP is optimal reservoir release. Input and output optimization results from Dynamic Programming are displayed in **Table 1**.

Table 1. Input and output optimization with CSUDP

Stage	Input CSUDP		Output CSUDP		
	Inflow (million m³)	Demand (million m³)	Volume (million m³)	Release (million m³)	Deviation -
1	7,18	3,04	20,13	3,03	0,003
2	8,37	2,23	17,12	2,21	0,008
3	9,72	2,93	17,94	2,90	0,010
4	9,25	2,97	17,25	3,03	0,021
5	6,56	3,05	17,12	3,03	0,004
6	4,92	3,70	17,12	3,72	0,005
7	3,82	3,34	16,43	3,32	0,006
8	3,02	3,04	16,71	3,08	0,011
9	2,18	3,04	16,43	2,97	0,024
10	2,93	2,23	15,47	2,21	0,010
11	2,61	1,96	16,02	2,03	0,040
12	4,35	1,40	16,43	1,39	0,009
13	2,98	1,03	18,76	0,98	0,049
14	1,52	1,22	19,17	1,12	0,082
15	0,32	1,22	19,03	1,15	0,053
16	0,00	1,22	17,94	1,11	0,085
17	0,05	0,39	16,57	0,45	0,163
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....

Stage	Input CSUDP		Output CSUDP		
	Inflow (million m³)	Demand (million m³)	Volume (million m³)	Release (million m³)	Deviation -
.....	.....	.....	.....	.....	.....
600	5,89	3,04	11,09	3,08	0,013

Source : Input and output dynamic programming optimization analysis with CSUD

3.1.2 Multi Linear Regression Analysis with SPSS

Multi linear regression analysis with SPSS was able to be processed easily. All variables that affected the operation of the reservoir were included as initial data input. Then it proceeded by running the software step by step in the linear regression selection menu. The variables included were release (U), storage (X) and inflow discharge (I) in the previous period. The inflow used from seizure discharge for 25 years (600 periods). The output from SPSS is the most optimal release equation formula based on the regression test results. If the output produced from the SPSS analysis has more than one equation, then selecting the equation to use as the optimization release equation formula uses the equation that has the greatest R square value. Reservoir release formula is presented in **Table 2**.

Table 2. Reservoir release formula

No	Period	Release Formula			R^2
1	Jan-1	U_Jan-1	=	(0.197*X_Dec-2) + (0.345*I_Dec-2) -(0.247*I_Nov-2)	0.963
2	Jan-2	U_Jan-2	=	(0.054*X_Dec-2) + (0.060*X_Jan-1) + (0.105*I_Jan-1)	0.985
3	Feb-1	U_Feb-1	=	(0.143*X_Jan-2) + (0.043*X_Des-2)	0.992
4	Feb-2	U_Feb-2	=	(0.092*X_Feb-1) + (0.089*X_Jan-2)	0.992
5	Mar-1	U_Mar-1	=	(0.185*X_Feb-2) - (0.011*I_Jan-2)	0.998
6	Mar-2	U_Mar-2	=	(0.661*I_Mar-1)	0.985
7	Apr-1	U_Apr-1	=	(0.180*X_Mar-2) + (0.039*I_Mar-1)	1.000
8	Apr-2	U_Apr-2	=	(0.168*X_Mar-2)	0.998
9	May-1	U_May-1	=	(0.143*X_Apr-1)	0.872
10	May -2	U_May-2	=	(0.130*X_Apr-1)	0.997
11	Jun-1	U_Jun-1	=	(0.133*X_Apr-2) + (0.067*I_May-2) - (0.025*X_May-2)	0.999
12	Jun-2	U_Jun-2	=	(0.125*X_May-1) - (0.044*X_May-2)	0.998
13	Jul-1	U_Jul-1	=	(0.393*X_May-2) + (0.476*I_May-2) - (0.384*X_Jun-1)	0.997
14	Jul-2	U_Jul-2	=	(0.072*X_Jun-1)	0.987
15	Aug-1	U_Aug -1	=	(0.074*X_Jun-2)	0.982
16	Aug -2	U_Aug -2	=	(0.284*X_Jul-1) - (0.237*X_Aug-1) + (0.366*I_Jul-2)	0.989
17	Sep-1	U_Sep-1	=	(0.140*X_Jul-2) - (0.121*X_Aug-1)	0.978
18	Sep-2	U_Sep-2	=	(0.170*X_Aug-1) - (0.174*X_Sep-1) + (0.170*I_Aug-1) + (0.270*I_Aug-2)	0.991
19	Okt-1	U_Okt-1	=	(0.818*X_Aug-2) - (0.833*X_Sep-2) + (1.087*I_Aug-2) + (1.424*I_Sep-1) + (0.144*I_Sep-2)	0.999
20	Okt-2	U_Okt-2	=	(0.158*X_Okt-1) + (0.303*I_Okt-1)	0.961
21	Nov-1	U_Nov-1	=	(0.613*I_Okt-1) + (0.153*X_Okt-1)	0.925
22	Nov-2	U_Nov-2	=	(0.201*X_Nov-1) + (0.538*I_Nov-1)	0.931
23	Dec-1	U_Dec-1	=	(0.384*X_Okt-2) + (0.393*I_Nov-2) -(0.243*X_Nov-2)	0.956
24	Dec-2	U_Dec-2	=	(0.290*I_Dec-1) + (0.339*X_Nov-1) - (0.263*X_Nov-2)	0.947

Source : Output multi linear regression analysis with SPSS

3.2 Reservoir Simulation Analysis

The analysis of reservoir operation simulation aimed to evaluate the reservoir system and the operation performance of the reservoir against the release of the optimization results using the generated 25-year discharge inflow discharge. The simulation of the operation of Logung Reservoir was carried out in a period of 2 weeks for 25 years of operation or 600 biweekly reservoir operations and for the release of water the reservoir was targeted to be able to meet the irrigation needs of 2.850 Ha and raw water of 200 liters/second. Some of the assumptions used in the reservoir operation simulation process are :

1. The total release requirement is not allowed to exceed the total requirements in each period.
2. The simulation is carried out for 25 years according to the order in which the generation of seizure inflow.
3. The volume of storage at the beginning of the operation of the reservoir is equal to the initial storage volume of 20.15 million m³.

4. The minimum elevation of the reservoir is not allowed to be less than +75.50 m or 8.00 million m^3, in order to maintain reservoir conditions so that the dam's body stability is maintained.

Reservoir simulation analysis was calculated using tables with the help of Microsoft Excel, then the results are displayed in the form of reservoir elevation images from period 1 to 600. Reservoir elevation is presented in **Figure 1**.

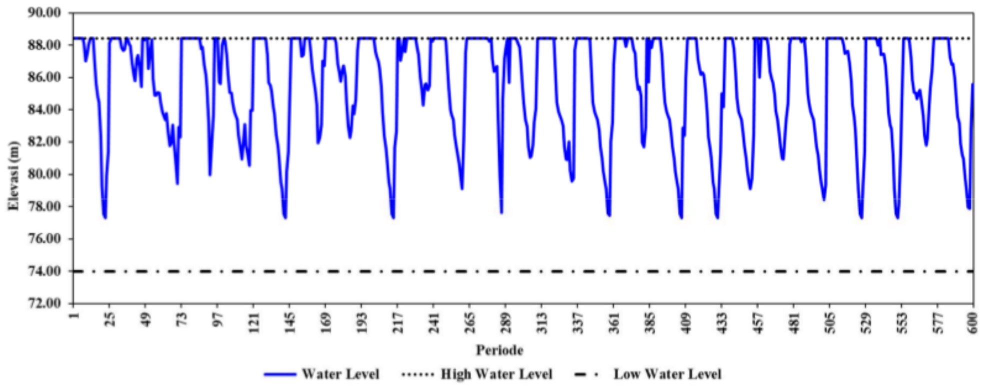

Figure 1. Reservoir elevation
Source : Calculating

3.3 Reservoir Performance Analysis
Reservoir performance analysis was based on the results of the optimization with the Implicitly Stochastic Dynamic Programming method. The data length used in the analysis of reservoir performance is for 25 years of operation or 600 biweekly reservoir operations. Reservoir performance is presented in **Table 3**.

Table 3. Reservoir performance

No	Item	Total	Unit
1	Reliability		
	The number of periods of success	482	periods
	The number of periods failed	118	periods
	The number of operating periods	600	periods
	Reliability	80,33	%
2	Resilience		
	Transition from success to failure	62	periods
	Number of failed periods	118	periods
	The duration of the average reservoir is in a failed state	1,9	-
	Resilience	52,54	%
3	Vulnerability		
	Number of failed periods	118	periods
	Vulnerability / total deficit	52,51	million m^3

Source : Calculating

4. Conclusion
From the research that has been done, it can be concluded that:
1. Optimization analysis of reservoir operation throughout the 25 years of operation using the Implicitly Stochastic Dynamic Programming method produced the most optimal release formula in each period.

2. Simulation analysis of the results of optimization modelling throughout the 25-year operating period or during the 600 periods resulted in 482 successful periods and 118 periods failed.
3. Analysis of reservoir performance based on the results of optimization and simulation modelling throughout the 25 years operating period produced a result stating its reliability = 80,33 %; resilience = 52,54 %; and vulnerability = 52,51 million m^3.

Optimization of Logung Reservoir Performance

ORIGINALITY REPORT

10%	7%	5%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	boris.unibe.ch Internet Source	5%
2	Submitted to Universiti Teknologi Malaysia Student Paper	2%
3	media.neliti.com Internet Source	1%
4	Submitted to Universitas Diponegoro Student Paper	1%
5	Submitted to School of Business and Management ITB Student Paper	1%
6	real.mtak.hu Internet Source	<1%
7	www.accessscience.com Internet Source	<1%
8	link.springer.com Internet Source	<1%
9	1pdf.net	

Internet Source

<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		

Optimization of Logung Reservoir Performance

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8