JPPIPA 11(5) (2025)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Validation of NRECA Parameters for Rainfall-to-Discharge Modeling in the Rejoso Watershed

Angelina Satya Putri[1*], Ery Suhartanto[2], Ussy Andawayanti[2]

[1]Master Program of Water Resources Engineering, University of Brawijaya, Malang, Indonesia.
[2]Department of Water Resources Engineering, University of Brawijaya, Malang, Indonesia.

Received: March 20, 2025
Revised: April 23, 2025
Accepted: May 25, 2025
Published: May 31, 2025

Corresponding Author:
Angelina Satya Putri
angelinasatya@student.ub.ac.id

DOI: 10.29303/jppipa.v11i5.11107

Abstract: The Rejoso Watershed in Pasuruan Regency is a water source for local needs and ecological balance. However, limited discharge data due to the absence of optimal measurement infrastructure poses a challenge for sustainable watershed management. This study aims to estimate river discharge using the NRECA method, with parameter optimization for PSUB and GWF achieved through a Genetic Algorithm. The novelty of this research lies in its integration of the NRECA method and Genetic Algorithm for improved discharge estimation in data-scarce regions. Calibration and validation were conducted using a 15:5 ratio, resulting in a Nash-Sutcliffe Efficiency (NSE) value of 0.5379, categorized as "Meets" based on the range defined (0.50–0.65), and a correlation coefficient of 0.7907, indicating a "Strong" linear relationship. Validation ensures the model's reliability beyond historical calibration data, addressing potential overfitting. These findings demonstrate the NRECA method's capability, supported by Genetic Algorithm optimization, as a practical alternative for discharge estimation in watersheds with limited data. Nevertheless, the model's performance remains sensitive to input data quality, emphasizing the need for better rainfall data. This approach contributes to improving water resource management in Rejoso and similar watersheds facing data limitations.

Keywords: Discharge; GWF; PSUB; Rainfall; Validation

Introduction

Discharge data on watersheds is needed to determine the amount of water in the river that can be used to meet the needs of living things in the vicinity (Ilham et al., 2022). The Rejoso watershed is located in Pasuruan Regency and has a role as a clean water supplier for Pasuruan and its surroundings. In addition, the watershed supports various vital activities such as agriculture, fisheries, and the lives of local communities (Amalia et al., 2023). Several factors, such as the amount of rainfall, infiltration, surface runoff and local climatic conditions, can affect water availability in an area (Suhartanto & Priyantoro, 2012). The ever-increasing water demand of local communities is not proportional to the amount of water available in the watershed, leading to an imbalance in watershed management. Therefore, we need to know the amount of discharge present in the river (Kurniawan et al., 2019). However, streamflow discharge data is often incomplete due to damage to discharge measuring instruments and measurement errors (Abdillah et al., 2020). Predicting streamflow discharge can be difficult in the absence of sufficient data (Fathoni et al., 2016). As a result, it is necessary to convert rainfall to discharge, a modelling that converts rainfall data into discharge data (Putri et al., 2022). The NRECA method, which is based on the KP-01 (Irrigation Network Planning Criteria), was used in this study (Directorate General of SDA, 2013). According to the criteria, the NRECA method is considered one of the standards used in discharge modelling calculations. This method involves watershed characteristic parameters such as Percentage of Sub-Surface (PSUB) and Groundwater Flow (GWF). Genetic Algorithm will be used to determine these two parameters (Hawari et al., 2025). The use of Genetic

How to Cite:
Putri, A. S., Suhartanto, E., & Andawayanti, U. (2025). Validation of NRECA Parameters for Rainfall-to-Discharge Modeling in the Rejoso Watershed. *Jurnal Penelitian Pendidikan IPA*, *11*(5), 1081–1088. https://doi.org/10.29303/jppipa.v11i5.11107

Algorithm is considered suitable for the optimization of PSUB and GWF parameters in the context of NRECA modeling due to its ability to explore a wide parameter space and handle non-linear objective functions, thus increasing the chances of finding the optimal combination of parameters. Genetic Algorithm is used to solve complex optimization problems, which allows it to produce the best and most effective solution (Syakiroh et al., 2024).

Calibration is the process of adjusting model parameters so that simulation results are close to actual conditions in the field (Jian et al., 2021). In the NRECA method, calibration is focused on optimising the PSUB and GWF parameters that represent the hydrological response of the watershed (Widyaningsih et al., 2021). Although the NRECA method also involves other parameters, such as the initial Moisture Storage (Wo) and the Initial Groundwater Storage, their determination follows a set of standard trial-and-error procedures based on KP-01 guidelines. For instance, the Wo value in January must be trialed until the difference between January and December storage does not exceed 200 mm, and for subsequent months, Wo is updated based on the previous month's value plus the change in storage. Similarly, the Initial Groundwater Storage value is trialled starting from 2 mm in January, and in subsequent months, it is updated by subtracting the previous month's groundwater flow from the previous month's groundwater storage.

However, based on the KP-01 criteria, calibration is primarily needed for PSUB and GWF because these parameters directly control the partitioning of rainfall into subsurface flow and groundwater flow, which are critical for accurately simulating streamflow in the watershed. In contrast, Wo and Initial Groundwater Storage are updated dynamically each month using deterministic equations once initial estimates are set, and thus are not subject to the same monthly calibration process. This approach ensures that the model remains consistent with the standards set by KP-01 while focusing the calibration effort on the most hydrologically influential parameters.

Sulistiyono (2015) emphasised the importance of selecting a calibration period that includes seasonal variations, in order to obtain stable and reliable parameters for long-term predictions. Effective validation ensures that model parameters, such as PSUB and GWF, obtained during calibration, are reliable for future predictions. This is in line with the view of Biondi et al. (2011), who emphasised the importance of validation in assessing the generalisability of hydrological models and avoiding over-reliance on historical data.

Method

This research is located in the Rejoso watershed, Pasuruan Regency which has an area of 285.355 km^2 with 7 rainfall stations namely Lumbang, Panditan, Puspo, Ranu Grati, Sidepan, Winongan, Gading which after the Data Quality Test will be carried out to find the average rainfall of the area which will be used in research to convert rainfall into discharge, as well as AWLR stations as a comparison and reference used for analysis with the NRECA method.

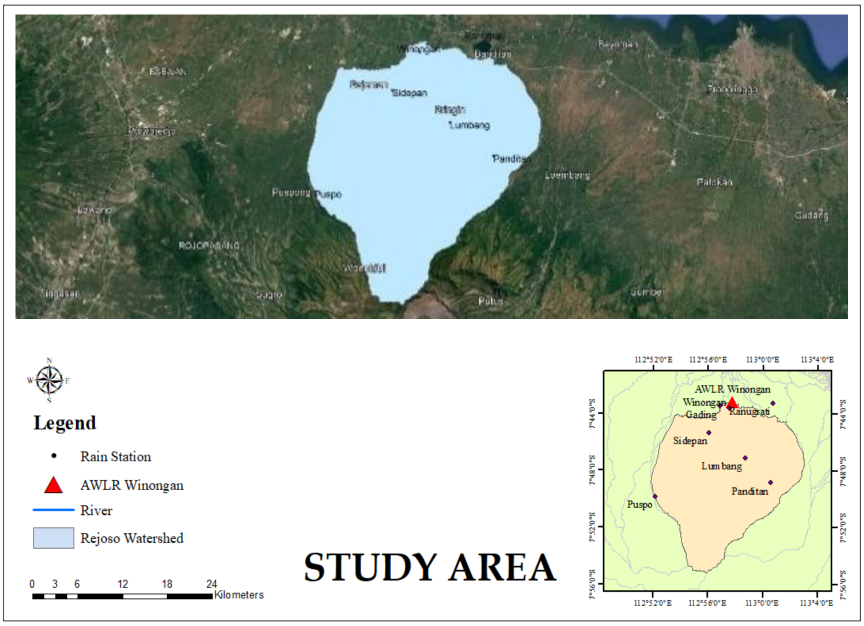

Figure 1. Rejoso Watershed

Data Preparation

The first step is to collect data from various related agencies needed for this research such as rainfall data, climatology data and discharge data from various agencies.

Calibration Data

Prepare NRECA Method calculation data for 20 years (2004-2023) that has been searched for parameters (PSUB & GWF) using the Genetic Algorithm with Solver Add-Ins on Microsoft Excel with the Evolutionary Method because this method is very efficient and accurate (Hawari et al., 2025). Solver in Microsoft Excel provides three solution methods, namely Simplex LP for linear functions, Nonlinear GRG for nonlinear functions with fast processing but sensitive to initial values, and Evolutionary for complex nonlinear optimization (Nisa et al., 2024). The Evolutionary method was chosen because it is more stable to the complexity of the objective function and constraints, and is able to continuously explore the solution space to find the best result. In this study, the Solver was used with the Evolutionary method to minimize the squared difference between model discharge and AWLR discharge, with PSUB 0.3-0.9 and GWF 0.01-0.8 constraints.

Composition Division

Performing data division as much as 5 compositions, namely 15: 5, 16:4, 17:3, 18:2, 19:1 with the aim of the evaluation process of the NRECA model to obtain an overview of the level of uncertainty of the NRECA model that has been generated from the calibration process. The validation data used is data that is outside the data period for calibration. Calibration and validation division stage by dividing monthly period data into 5 groups (15: 5, 16: 4, 17: 3, 18: 2, and 19: 1).

Statistical Indicators for Validation Analysis
Nash-Sutchliffe Efficiency (NSE)

This test aims to ensure the accuracy of the correlation between the measured data and the calculated data. The equation used is:

$$NSE = 1 - \frac{\sum_{i=1}^{N}(Pi - Qi)^2}{\sum_{i=1}^{N}(Pi - \bar{P}i)^2} \quad (1)$$

Decription:
NSE = Nash-Sutchliffe coeficient
P_i = Field observation value (m^3/dt)
Q_i = Modeling result value (m^3/dt)
$\bar{P}_i$ = Average value of field observation (m^3/dt)
N = Number of data

Table 1. Classification of NSE value

Value Range	Performance Rating
$0.75 < NSE \leq 1.00$	Very Good
$0.65 < NSE \leq 0.75$	Good
$0.50 < NSE \leq 0.65$	Meets
$NSE \leq 0.50$	Does Not Meet

Source: Moriasi et al. (2007)

Correlation Coefficient (R)

This test is used to determine whether the linear correlation between the two variables is strong or not. The equation used is:

$$R = \frac{N\sum_{i=1}^{N} PiQi - \sum_{i=1}^{N} Pi \times \sum_{i=1}^{N} Qi}{\sqrt{\sum_{i=1}^{N} Pi^2 - (\sum_{i=1}^{N} Pi)^2}\sqrt{\sum_{i=1}^{N} Qi^2 - (\sum_{i=1}^{N} Qi)^2}} \quad (2)$$

Description:
R = Correlation coefficient
Pi = Field observation value (m3/dt)
Qi = Modeling result value(m^3/dt)

After obtaining the R value, the value will be classified based on the level of relationship, the following is a clasification table of criteria from the value of the correlation coefficient.

Table 2. Classification of R value

Value Range	Level of Relationship Linkage
0.00 – 0.19	Very Low
0.20 – 0.39	Low
0.40 – 0.59	Medium
0.60 – 0.79	Strong
0.80 – 1.00	Very Strong

Source: Sugiyono (2007)

Result and Discussion

PSUB and GWF Parameter Values with Genetic Algorithm

After conducting Data Quality Test, Regional Average Rainfall and Potential Evapotranspiration, what is done is to find the value of PSUB and GWF parameters for NRECA model discharge calculations with Genetic Algorithm using the help of Solver Add-Ins in Microsoft Excel. After obtaining the PSUB and GWF parameter values, look for the minimum, average or maximum values. Later the value will be used for the validation process based on the composition that has been determined, namely 15:5, 16:4, 17:3, 18:2 and 19:1. The following are the results of the PSUB and GWF (Min, Avg and Max) values that will be used for further calculations.

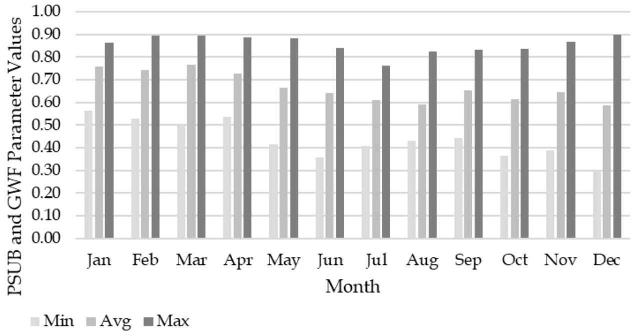

Figure 2. PSUB bar graph

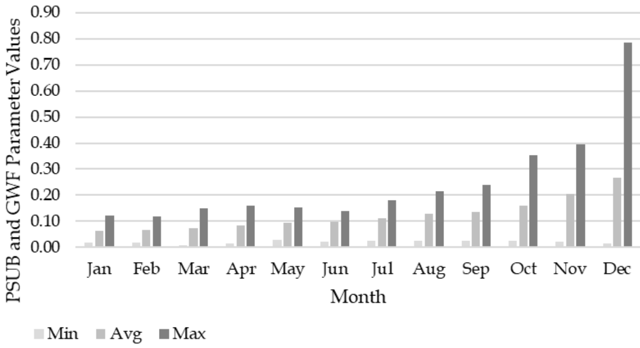

Figure 3. GWF bar graph values

Calibration NRECA Method

The calibration stage is carried out to adjust the model parameters, in this case PSUB and GWF in the NRECA method, so that the model output values are close to the observation data (Seisia et al., 2022). This process involves finding the best combination of parameters that can optimally represent the hydrological characteristics of the watershed in a certain period (Nurviana et al., 2023). Parameter selection is carried out iteratively using certain algorithms (Cheng et al., 2002), such as Genetic Algorithms, to minimize errors between simulation results and actual data (Ndiritu & Daniell, 2001). The following are the results of the 20-year calibration process (2004-2023).

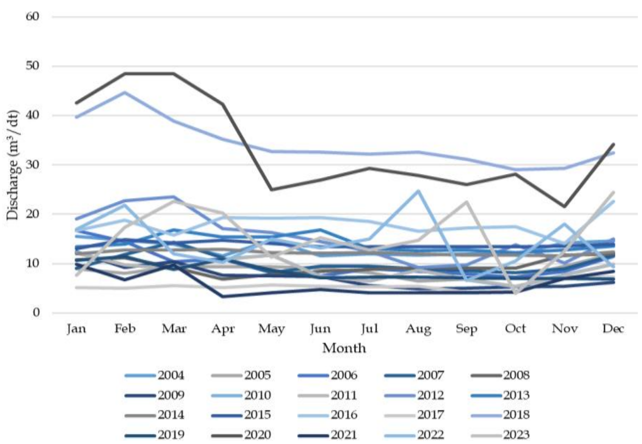

Figure 4. NRECA method discharge results with genetic algorithm in 20 years (2004-2023)

The following are the results of the NSE values and Correlation Coefficient for 20 years from 2004-2023 whose parameters have been searched using the Genetic Algorithm.

Table 3. Recapitulation of NSE results and correlation coefficients for 2004-2023

Year	NSE		Correlation	
	Value	Interp.	Value	Interp.
2004	1.00	VG	1.00	VG
2005	1.00	VG	1.00	VG
2006	1.00	VG	1.00	VG
2007	1.00	VG	1.00	VG
2008	1.00	VG	1.00	VG
2009	1.00	VG	1.00	VG
2010	1.00	VG	1.00	VG
2011	1.00	VG	1.00	VG
2012	1.00	VG	1.00	VG
2013	1.00	VG	1.00	VG
2014	0.95	VG	0.99	VG
2015	0.99	VG	1.00	VG
2016	1.00	VG	1.00	VG
2017	1.00	VG	1.00	VG
2018	1.00	VG	1.00	VG
2019	1.00	VG	1.00	VG
2020	1.00	VG	1.00	VG
2021	1.00	VG	1.00	VG
2022	1.00	VG	1.00	VG
2023	1.00	VG	1.00	VG

Composition for Calibration: Validation

Calibration serves to train the model in obtaining the optimum parameters, namely PSUB and GWF, while validation is used to test the model's ability to make predictions on data that is not included in the calibration process (Trilita et al., 2021). Dividing the data into several calibration-validation compositions, such as 15:5 to 19:1, is done to evaluate the most effective data ratio in producing the best model performance. The best composition reflects the ideal data proportion that is able to maintain a balance between prediction accuracy and the risk of overfitting. In addition, this ratio indicates that the resulting parameters (PSUB and GWF) are in the most stable and reliable state to be applied to future predictions. This indicates that the model not only adapts to historical data, but is also able to represent the hydrological characteristics of the watershed as a whole. Therefore, the best composition can be recommended as a reference in model development in similar watersheds, as well as a scientific basis for analyzing future land use and climate change scenarios (Hatmoko et al., 2020).

This stage aims to determine the comparison between the calculated discharge data and the discharge data in the field (AWLR). In the calibration and validation stage, the year data used for calibration is the data outside the year for validation, the monthly period data was divided into several groups with a total of 20 years of research data, as follows.

Table 4. Composition of calibration and validation divisions

Komp.	Calibration	Validation
15 : 5	15 Years (2004 - 2018)	5 Years (2019 - 2023
16 : 4	16 Years (2004 – 2019)	4 Years (2020 – 2023)
17 : 3	17 Years (2004 - 2020)	3 Years (2021-2023)
18 : 2	18 Years (2004 - 2021)	2 Years (2022-2023)
19 : 1	19 Years (2004 - 2022)	1 Year (2023)

NRECA Validation Results with Best Composition

Validation is a crucial stage in the hydrological modelling process using the NRECA method (Hidayat & Nugroho, 2025), as it serves to test the model's ability to make predictions on data that is not involved in the calibration process. After calibration with several historical data compositions, the best composition was obtained at a ratio of 15:5, where 15 years of data were used for calibration and the remaining 5 years for validation. The selection of this composition is based on the statistical evaluation results that show the most optimal model prediction performance, namely by looking at the Nash-Sutcliffe Efficiency (NSE) value and the correlation coefficient (R) value.

Table 5. Calculation of NRECA method discharge validation test components with 5 years of data (2019-2023) monthly period

AWLR (P)	NRECA (Q)	P-Q	(P-Q)2	(P-P*)	(P-P*)2
10.80	11.33	-0.53	0.28	-4.80	23.01
11.60	13.06	-1.46	2.12	-4.00	15.98
8.94	12.27	-3.33	11.08	-6.66	44.36
11.09	12.46	-1.37	1.88	-4.51	20.32
8.75	7.27	1.49	2.21	-6.85	46.86
7.23	6.69	0.54	0.29	-8.37	70.04
7.28	6.59	0.70	0.48	-8.31	69.13
7.30	6.48	0.81	0.66	-8.30	68.91
7.22	6.25	0.97	0.94	-8.38	70.24
7.06	6.25	0.80	0.64	-8.54	72.94
7.04	6.86	0.19	0.03	-8.55	73.16
6.97	6.88	0.08	0.01	-8.63	74.46
42.84	38.47	4.37	19.09	27.24	742.17
48.63	40.05	8.58	73.53	33.03	1091.16
48.47	34.41	14.06	197.71	32.87	1080.62
42.47	33.46	9.01	81.21	26.87	722.15
25.16	34.99	-9.83	96.64	9.56	91.45
27.09	31.53	-4.44	19.73	11.49	132.08
29.59	31.06	-1.47	2.15	13.99	195.80
27.86	30.56	-2.70	7.28	12.26	150.38
26.02	29.46	-3.44	11.83	10.42	108.63
28.55	29.49	-0.94	0.88	12.95	167.77
21.79	32.84	-11.05	122.04	6.19	38.35
34.16	36.42	-2.26	5.10	18.56	344.58
9.95	16.34	-6.39	40.83	-5.65	31.90
6.73	16.92	-10.19	103.77	-8.87	78.59
9.80	21.08	-11.27	127.09	-5.80	33.58
3.37	9.57	-6.20	38.47	-12.23	149.53
4.09	7.64	-3.56	12.65	-11.51	132.51
4.80	9.54	-4.74	22.43	-10.80	116.56
4.19	7.24	-3.05	9.30	-11.40	130.03
4.19	7.13	-2.94	8.63	-11.41	130.15
4.17	6.87	-2.70	7.28	-11.43	130.54
4.21	6.94	-2.73	7.45	-11.39	129.67
7.00	16.59	-9.58	91.81	-8.59	73.84
8.50	36.38	-27.88	777.39	-7.10	50.38
16.98	21.60	-4.62	21.35	1.38	1.91
21.94	19.34	2.61	6.79	6.35	40.28
12.08	26.50	-14.42	207.82	-3.52	12.36
10.23	12.41	-2.18	4.74	-5.37	28.83
15.09	25.22	-10.13	102.59	-0.51	0.26
13.17	12.80	0.37	0.14	-2.43	5.88
15.10	13.30	1.79	3.21	-0.50	0.25
24.81	11.81	13.00	169.11	9.22	84.92
6.59	11.38	-4.79	22.96	-9.01	81.10
10.53	14.50	-3.97	15.78	-5.07	25.71
18.04	25.29	-7.25	52.59	2.44	5.97
9.44	26.72	-17.28	298.76	-6.16	37.96
7.71	20.78	-13.07	170.85	-7.89	62.28
17.55	26.61	-9.06	82.05	1.95	3.82
22.62	29.44	-6.83	46.59	7.02	49.26
20.50	19.74	0.76	0.57	4.90	24.04
11.46	18.70	-7.24	52.47	-4.14	17.14
15.38	17.22	-1.84	3.37	-0.22	0.05
12.99	16.96	-3.97	15.75	-2.61	6.82
14.86	16.68	-1.82	3.32	-0.73	0.54
22.63	16.08	6.55	42.91	7.04	49.52
4.03	16.10	-12.07	145.77	-11.57	133.88
12.64	17.72	-5.08	25.80	-2.96	8.74
24.57	17.59	6.98	48.74	8.97	80.53

After several calculations on the 5 compositions, the best composition will be selected. The following are the results of the NRECA method calculations with the best composition.

Table 6. 5-year validation calculation results (2019-2023)

Method	Value	Interpretation
NSE	0.5379	M
Correlation	0.7907	S

P* = 15.60
SUM $(P-Q)^2$ = 3448.95
SUM $(P-P^*)^2$ = 7463.88

The selection of this composition is based on the statistical evaluation results that show the most optimal model prediction performance, namely with a Nash-Sutcliffe Efficiency (NSE) value of 0.5379 which is in the 'Satisfactory' category, and a correlation coefficient (r) value of 0.7907 which is in the 'Strong' category.

Validation with a 15:5 composition proves that the calibrated model is not only able to adjust to historical data patterns, but also has good predictive power for data outside the training period. This indicates that the PSUB and GWF parameters obtained from the genetic algorithm are quite stable and can represent the hydrological conditions of the watershed consistently. The success of this validation is also an indicator that the NRECA method can be relied upon as an alternative discharge estimation in areas that experience limited daily discharge data or do not have adequate measuring instruments.

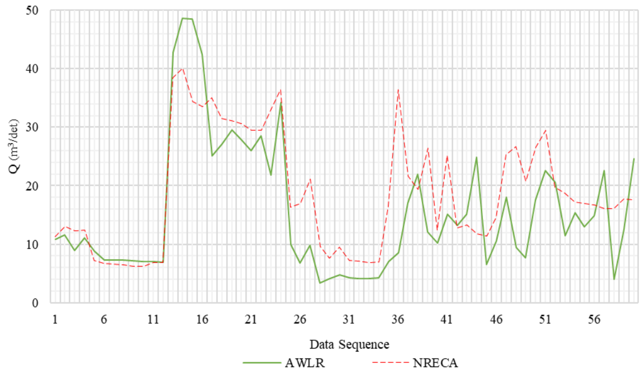

Figure 5. 5-year validation graph (2019-2023) comparison of AWLR discharge and NRECA model discharge

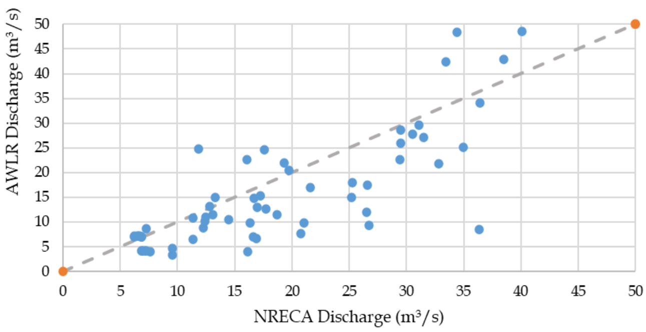

Figure 6. 5-year validation scatter plot graph (2019-2023) comparison of AWLR discharge and NRECA discharge

The following is the recapitulation of the calibration and validation results with the results of the NSE value and the Coefficient of Correlation value for each composition. Indeed, there are results that "Do not meet" or have a "Very Low" relationship and that's okay because that's the validation process which means we don't take all of it but the best.

Thus, the 15:5 composition can be recommended as a rational approach for discharge modeling in the Rejoso watershed and has the potential to be adapted to other watersheds with similar characteristics. This validation not only strengthens the reliability of the model, but also provides a strong scientific basis for the application of the model in water resources management planning scenarios, such as land use change and long-term climate projections.

Table 7. Recapitulation of calibration and validation calculation results

Period		NSE		Coef. Correlation	
		Value	Interp.	Value	Interp.
Calibration	15	1.00	VG	1.00	VS
Validation	5	0.54	M	0.79	K
Calibration	16	1.00	VG	1.00	VS
Validation	4	0.41	DM	0.77	S
Calibration	17	1.00	VG	1.00	VS
Validation	3	-1.77	DM	0.35	L
Calibration	18	1.00	VG	1.00	VS
Validation	2	-1.83	DM	0.13	VL
Calibration	19	1.00	VG	1.00	VS
Validation	1	-1.48	DM	0.17	VL

Conclusion

This study successfully applied the NRECA method combined with Genetic Algorithm optimization through Microsoft Excel Solver (Evolutionary method) to estimate river discharge in Rejoso Watershed, Pasuruan. The focus of the calibration is on two key parameters, namely Percentage of Sub-Surface (PSUB) and Groundwater Flow (GWF), as they directly affect the formation of underground flow and groundwater flow in the NRECA model. Data for 20 years (2004-2023) were used for calibration and validation processes with five apportionment compositions (15:5, 16:4, 17:3, 18:2, and 19:1) to evaluate model uncertainty. The best validation results were obtained at 15:5 (15 years for calibration and 5 years for validation), with a Nash-Sutcliffe Efficiency (NSE) value of 0.5379, which is categorized as "Meets" ($0.50 < NSE \leq 0.65$), and a correlation coefficient (R) of 0.7907, which indicates a "Strong" linear relationship ($0.60 < R < 0.79$). The success of this validation confirms that the PSUB and GWF parameters obtained through Genetic Algorithm optimization are able to represent the hydrological characteristics of the watershed consistently, both on historical data and data outside the calibration period. This proves that the model is not only overfitting to the training data, but also has good predictive ability. However, although a strong correlation was achieved, it should be noted that a high correlation does not necessarily guarantee the accuracy of predicting the correct discharge value, as the correlation only describes the strength of the linear relationship, not the suitability of the predicted value. In addition, the success of this model remains dependent on the quality of the input data, particularly the rainfall data. This approach offers a practical solution for discharge estimation in areas with limited discharge measurement data, and can serve as a basis for water resources management, watershed conservation planning, and adaptation to land use change and climate change in the future. The 15:5 composition can be recommended for similar model applications in other watersheds with similar characteristics.

Acknowledgments
The authors would like to express their gratitude to Dinas Pekerjaan Umum Sumber Daya Air (DPUSDA) of East Java Province and Badan Meteorologi, Klimatologi dan Geofisika Karangploso, East Java.

Author Contributions
The composition of this written work was facilitated by the guidance of two supervisors, Dr. Ir. Ery Suhartanto, ST., MT., IPU., ASEAN Eng., and Prof. Dr. Ir. Ussy Andawayanti, MS., IPM., ASEAN Eng., for data validation and data analysis.

Conflicts of Interest
The authors declare no conflict of interest.

Funding
This research was self-funded by the first author.

References

Abdillah, R., Harisuseno, D., & Sisinggih, D. (2020). Application of Rainfall Hydrology Model Using Block-Wise Topmodel Muskingum-Cunge (BTOPMC) Application in Lesti Sub-Based River. *Jurnal of Water Resources Engineering (JTP)*, *3*(2), 10. Retrieved from https://garuda.kemdikbud.go.id/documents/detail/1818535

Amalia, N. N., Suhartanto, E., & Prasetyorini. L. (2023). Conservation Efforts for Erosion Based on Geographic Information Systems in Rejoso Watershed, Pasuruan Regency. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *3*(2). https://doi.org/10.21776/ub.jtresda.2023.003.02.064

Biondi, D., Freni, G., Iacobellis, V., Mascaro, G., & Montanari, A. (2011). Validation of Hydrological Models: Conceptual Basis, Methodological Approaches and a Proposal for a Code of Practice. *Journal of Hydrology*, *403*(3-4), 196–209. https://doi.org/10.1016/j.jhydrol.2011.03.035

Cheng, C. T., Ou, C. P., & Chau, K, W. (2002). Combining A Fuzzy Optimal Model with a Genetic Algorithm to Solve Multi-Objective Rainfall–Runoff Model Calibration. *Journal of Hidrology*, *268*(1-4), 72-86. https://doi.org/10.1016/S0022-1694(02)00122-1

Directorate General of SDA. (2013). *Irrigation Planning Standards Planning Criteria Irrigation Network Planning Section KP-01*. Jakarta: Kementerian ESDM.

Fathoni, S., Dermawan, V,. & Suhartanto, E. (2016). Analysis of the Effectiveness of Rain Station Post Network Density in Kedungsoko Watershed Using Artificial Neural Network. *Jurnal of Water Resources Engineering (JTP)*, *7*(1), 129-138. Retrieved from https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/287

Hatmoko, W., Levina, L., & Diaz, B. (2020). Comparison of Rainfall-Runoff Models for Climate Change Projection – Case Study of Citarum River Basin, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *423*. https://doi.org/10.1088/1755-1315/423/1/012045

Hawari, H., Suhartanto, E., & Lufira, R, D. (2025). Conversion of Rainfall Varieties into Discharge Using the NRECA Method with Genetic Algorithm in the Gembong Watershed, Pasuruan Regency. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *5*(1). https://doi.org/10.21776/ub.jtresda.2025.005.01.067

Hidayat, M., & Nugroho, H. (2025). Comparison of Rainfall-Runoff Models with F.J. Mock and NRECA to Determine Water Availability of Rukoh Reservoir, Aceh. *TEKNIK*, *46*(1), 73-86. https://doi.org/10.14710/teknik.v46i1.67951

Ilham, M., Suhartanto, E., & Fidari, J. S. (2022). TRMM (Tropical Rainfall Measuring Mission) Rain Analysis into Discharge with the F.J. Mock Method in the Bango Watershed. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *2*(1), 509-521. https://doi.org/10.21776/ub.jtresda.2022.002.01.42

Jian, J., Ryu, D., & Wang, Q, J. (2021). A Water-Level Based Calibration of Rainfall-Runoff Models Constrained by Regionalized Discharge Indices. *Journal of Hydrology*, *603*, 126937. https://doi.org/10.1016/j.jhydrol.2021.126937

Kurniawan, A. R., Bisri, M., & Suhartanto, E. (2019). Drought Analysis in the Bedadung Watershed Based on Geographic Information System (GIS). *Jurnal of Water Resources Engineering (JTP)*, *10*(2), 97–109. https://doi.org/10.21776/ub.pengairan.2019.010.02.03

Moriasi, D. N., Arnold, J. G., Liew, M. W. V., Bingner, R, L., Harmel, R, D., & Veith, T, L. (2007). *Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations*. The American Society of Agricultural and Biological Engineers. https://doi.org/10.13031/2013.23153

Ndiritu, J. G., & Daniell, T. M. (2001). An Improved Genetic Algorithm for Rainfall-Runoff Model Calibration and Function Optimization. Mathematical *and Computer Modelling*, *33*(6-7), 695-706. https://doi.org/10.1016/S0895-7177(00)00273-9

Nisa, Z., Suhartanto, E., & Wahyuni, S. (2024). Application of Genetic Algorithm in Rain Variation Conversion into Discharge Using FJ. Mock Method in Rejoso Watershed. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *4*(2). https://doi.org/10.21776/ub.jtresda.2024.004.02.150

Nurviana, S. C. K., Suhartanto, E., & Harisuseno, D. (2023). Comparison of Rainfall to Discharge Conversion Methods with FJ. Mock and NRECA in Gandong Watershed, Magetan Regency. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *3*(1). https://doi.org/10.21776/ub.jtresda.2023.003.01.03

Putri, A. S., Suhartanto, E., & Fidari, J. S. (2022). Comparison of the Methods of Rainfall Transformation to Discharge with FJ. Mock and NRECA Method in Rejoso Watershed, Pasuruan Regency. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *3*(2), 078-092. https://doi.org/10.21776/ub.jtresda.2023.003.002.07

Seisia, C, T., Setyandito, O., Juliastuti, J., & Haripriambodo, T. (2022). Water Reliability Analysis in Industrial and Residential Area, Based on NRECA Method Using ArcGIS Software. *IOP Conference Series: Earths and Environmental Science*, *998*. https://doi.org/10.1088/1755-1315/998/1/012007

Sugiyono, S. (2007). *Quantitative Qualitative and R&D Research Methods*. Bandung: Alfabeta.

Suhartanto, E., & Priyantoro, D. (2012). Study of Watershed Condition Assessment and Its Implications for River Discharge Fluctuations (Case Study on Jangkok Sub-Das, Lombok Island). *Jurnal of Water Resources Engineering (JTP)*, *3*(1), 1–5. Retrieved from https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/139

Sulistiyono, H. (2015). *Calibration and Validation of Hydrological Model Using NRECA Method in Kodina* Watershed. Memorial University Research Repository. Retrieved from https://research.library.mun.ca/11491/1/Sulistiyono_Heri.pdf

Syakiroh, S., Suhartanto, E., & Wahyuni, S. (2024). Application of FJ. Mock Methodto Convert Rainfall to Discharge Using Genetic Algorithm in Welang Watershed Pasuruan District. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *4*(2), 1567-1577. https://doi.org/10.21776/ub.jtresda.2024.004.02.155

Trilita, M. N., Suryandari, W., & Handajani, N. (2021). Water Availability Study Using NRECA Model (Embung Sei Fatimah North Kalimantan Case Study). *IOP Conference Series: Earth and Environmental Science*, *1125*. https://doi.org/10.1088/1757-899x/1125/1/012095

Widyaningsih, K, W., Harisuseno, D., & Soetopo, W. (2021). Comparison of FJ. Mock and NRECA Methods for Rainfall Transformation into Discharge in Metro Watershed, Malang Regency, East Java. *Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDA)*, *1*(1). https://doi.org/10.21776/ub.jtresda.2021.001.01.05