Journal of Mechanical, Civil, and Industrial Engineering
ISSN: 2709-0809
DOI: 10.32996/jmcie
Journal Homepage: www.al-kindipublisher.com/index.php/jmcie

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| RESEARCH ARTICLE

Sensitivity Analysis of Mock and NRECA Method Parameters on Water Availability in the Jangkok Hulu Watershed

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| ABSTRACT
The Jangkok watershed, as one of the watersheds with high utility, plays an important role as a supplier of supplementary water to the communities living in the surrounding area. If there is a decrease in base flow in the Jangkok Watershed, it will have a significant impact on the irrigation water supply in Jangkok-Babak-Jurang Sate, raw water supply, and industrial water in Mataram City and West Lombok Regency. Because the Jangkok watershed is widely used for low flow management in the form of river and spring water, water flow availability can be obtained using the F.J Mock and NRECA methods. Each parameter has its own sensitivity that can directly affect changes in water availability. The parameter with the greatest sensitivity is determined based on the average deviation percentage and discharge change. The initial stage involved a calibration process with Qdefault results for the Mock and NRECA methods of 1.261 m^3/dt and 0.968 m^3/dt, respectively. Next, sensitivity analysis was performed using calibrated default parameters with overestimate and underestimate conditions of 5%, 10%, 15%, and 20%. Based on the results of the sensitivity analysis of the F.J. Mock Method, the parameter with the highest sensitivity was *the Groundwater Recession Constant* (k) under an underestimate condition of 20%, which affected the increase in water availability discharge in January 2024 to 6.457 m^3/dt with an average deviation of 245.90%. In the NRECA Method, the parameter with the highest sensitivity was *Percent Sub Surface* (PSUB) under the 20% underestimate condition, which influenced the increase in water availability discharge in January 2024 to 0.993 m^3/dt with an average deviation of 20.08%.

| KEYWORDS
sensitivity analysis, parameters, Mock, NRECA, water availability

| ARTICLE INFORMATION
ACCEPTED: 02 December 2025 **PUBLISHED:** 15 December 2025 **DOI:** 10.32996/jmcie.2025.6.5.3

1. Introduction
The Jangkok watershed, as one of the watersheds with high utility, plays a major role for the communities living in its vicinity. Based on the Academic Paper on Integrated Watershed Management by the West Nusa Tenggara DLHK, the Jangkok watershed area is dominated by forest ecosystems, especially in the upstream area. The flow of the Jangkok River is also connected to the flow of the Babak River, which is referred to as an interconnection, making this flow a major supplier of water for various purposes. The Jangkok-Babak-Jurang Sate HLD channel carries water from the Jangkok Dam, Sesaot Feeder Dam, and Keru Feeder Dam (Siswadi et al., 2021). In addition, the Jangkok watershed is known to supply water through the Sesaot-Gebong supply channel (Nani, 2020). Therefore, the Jangkok watershed plays an important role in providing water for the central and downstream areas, which are predominantly settled.

During long dry seasons, river discharge tends to decrease, making it necessary to determine base flow given its important role in regulating seasonal river flow distribution, maintaining aquatic habitats, and utilizing river systems (Primadita et al., 2023) . Another fact states that silting has occurred at the Sesaot Dam due to sediment transport from the Jangkok River, which directly affects silting in the HLD channel and causes a reduction in the water supply in the channel (Saadi et al., 2016) . If there is a decrease in base flow in the Jangkok River Basin (DAS), it will have a significant impact on the irrigation water supply for the Jangkok-Babak-Jurang Sate rice fields, raw water supply, and industrial water in Mataram City and West Lombok Regency.

Because the Jangkok watershed is widely used for low flow management in the form of river and spring water flows, the availability of water flow can be obtained using a method of analyzing rainfall transformation into discharge by the F.J Mock and NRECA Method. This involves parameters from the river basin that have an influence. Each parameter has its own sensitivity that directly affects changes in the availability of flow discharge, which can increase or decrease. Parameter sensitivity analysis can identify critical parameters and set management priorities (Frey and Patil, 2002). On the other hand, the F.J Mock and NRECA methods were chosen as the analysis methods in this study because they have types of parameters that can be calculated based on the characteristics of the watershed itself. Both methods are conceptual deterministic models that are well-suited for estimating water availability and discharge.

In this study, the initial parameter values will be determined through a calibration process using *Excel Solver* in *Microsoft Excel*, after which each parameter will be analyzed for sensitivity to determine the extent of change in water availability flow from both methods. This study aims to determine the effect of the sensitivity of the Mock and NRECA method parameters on changes in water availability flow and the extent of deviation. Parameters with high sensitivity can be utilized in water allocation applications, watershed management, or disaster mitigation.

2. Literature Review

This study was conducted by comparing the theoretical basis and methods used with several previous studies. Sakadiajeng (2023) calibrated the parameters of the Mock and NRECA methods in the Meninting watershed by looking at the correlation and *error* as well as the average deviation of the simulated discharge from the observed discharge. Prayudi et al. (2017) conducted a sensitivity analysis of parameters in HEC-HMS using the *Snyder Unit Hydrograph* runoff model. The parameters were tested gradually by locking other parameters, and the highest sensitivity values were found to be the *Initial* and *Constant Rate* parameters because the changes in runoff volume produced by these parameters were greater than those of other parameters. Marhendi (2014) . conducted a sensitivity analysis to determine the parameters that influence changes in the annual water flow system in the Kranggan Sub-Watershed. The calibrated parameters were then analyzed for sensitivity by increasing their values by 1 to 2 times the initial values. In the study Hidayat and Soekarno (2020) conducted a sensitivity analysis using *underestimate* and *overestimate* scenarios. In the *underestimate* scenario, the *default* parameter values were reduced by 25%, while in the *overestimate* scenario, the *default* parameter values were increased by 25%. Each parameter was reduced or increased once at a time, while the other parameter values remained constant. The Manning's n-pervious parameter was found to be a sensitive and important parameter in predicting flood volume, with an increase of 6.366% in flood volume.

3. Methodology

In this study, the rainfall-runoff transformation process was carried out using two methods, namely Mock and NRECA, with each runoff output calibrated using Excel Solver in Microsoft Excel. The calibration process included testing the suitability of the data between simulated runoff and observed runoff. The parameter sensitivity analysis process was carried out with underestimate and overestimate scenarios of 5%, 10%, 15%, and 20% one by one while keeping the other parameters constant. The calibration and sensitivity testing processes considered the Correlation Coefficient (R), Percentage Error (PE), Root Mean Square Error (RMSE), and Nash-Sutcliffe Efficiency (NSE). The parameter sensitivity results were then compared with the initial (default) parameter results, the magnitude of the deviation, and its effect on changes in water availability.

3.1 Research Location and Data

The research location is located in the Jangkok watershed, specifically in the upstream area determined based on the Aiknyet AWLR Post area with *a catchment area* of 65.60 km^2. The data used consists of rainfall data from the Gunung Sari Station, Sesaot Station, Keru Station, Santong Station, and Jurang Malang Station for the years 2015-2024, river flow data from the Aiknyet AWLR Post, and climatological data to calculate evapotranspiration as input for Mock and NRECA. To calculate rainfall in the area, the Thiessen Polygon method was used with the assistance of QGIS.

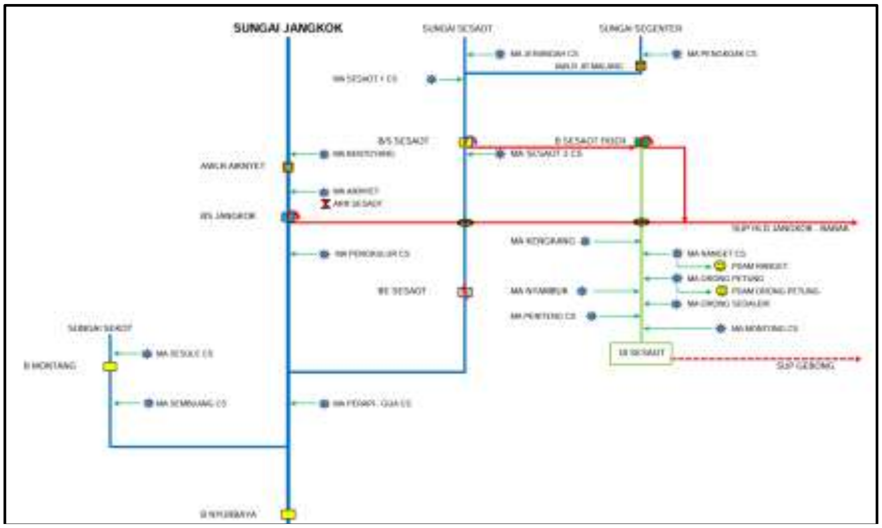


Figure1 . Schematic of the Jangkok River with the Aiknyet AWLR boundary

3.2 Regional Rainfall

The average rainfall value for the region was calculated by multiplying the rainfall data and the Thiessen coefficient from the influential stations. The influential stations were obtained using QGIS software with input coordinates from the Keru station, Jurang Malang station, Sesaot station, and Gunung Sari station.

3.3 Evapotranspiration

This calculation uses the FAO modified Penman method, which is influenced by several factors, namely relative humidity (RH), air temperature (T), wind speed (U2), and duration of sunshine ($\frac{n}{N}$) (Baskoro et al., 2024) . Data correction was carried out in advance to adjust the observation data to the elevation of the climatological station and the study area.

3.4 Mock

The F.J. Mock method is a method that applies the concept of *water balance* and is one of the methods used to analyze water balance based on monthly discharge calculations based on monthly rainfall data, evapotranspiration, soil moisture, and groundwater (Setiadi et al., 2022) . The parameters used are Infiltration Coefficient, Soil Moisture Capacity (SMC), Initial Soil Moisture (ISM), Initial Groundwater Storage (IGWS), Groundwater Recession Constant (k), Exposed Surface (m), and Percentage Factor (PF).

Table1 Parameter Range of the Mock Method

No	Parameter	F.J. Mock Method	
		Minimum	Maximum
1	*Infiltration Coefficient (if)*	0	1
2	*Soil Moisture Capacity (SMC)*	50	200
3	*Initial Soil Moisture (ISM)*	50	200
4	*Initial Groundwater Storage (IGWS)*	100	
5	*Groundwater Recession Constant (k)*	0	1
6	*Exposed Surface (m)*	10	50
7	*Percentage Factor (PF)*	5	30

Water Surplus is rainfall that has undergone evapotranspiration and fills *soil storage* (SS*). Water Surplus* directly affects infiltration and Direct runoff, which are components of Total Runoff discharge. *Soil Moisture Capacity* is the water content capacity of *the surface soil* layer per m^2. In calculating the SMC value, a range of 50 mm to 200 mm is used. Meanwhile, Initial Soil Moisture is the initial storage or remaining storage from the previous month, which is influenced by Soil Moisture Capacity. In baseflow calculations, the Groundwater storage value must first be determined using the *initial storage* value. The Groundwater Recession Constant (k) is the proportion of groundwater from the previous month that remains in the current month.

3.5 NRECA

The NRECA method structure is divided into two reservoirs, namely *moisture* storage and groundwater storage, and two runoff types, namely direct runoff (surface runoff) and baseflow (*groundwater storage*) (Saputri and Saves,2023) . This study used four NRECA parameters, namely Percent Sub Surface (PSUB), Ground Water Flow (GWF), Initial Soil Moisture Storage (ISMS), and Initial Groundwater Storage (IGWS). PSUB is a parameter that describes the characteristics of surface soil at a depth of 0-2 m, with a value of 0.3 for impermeable soil and 0.9 for permeable soil. Groundwater Flow (GWF) is a parameter that describes the characteristics of the inner soil at a depth of 0-2 m, with a value of 0.8 for impermeable soil and 0.2 for permeable soil. ISMS is a parameter that can affect the PSUB value, which has a direct influence on direct runoff. Meanwhile, the IGWS parameter is groundwater storage that affects the GWF value, which has a direct influence on total discharge.

Table2 . Parameter Range of the NRECA Method

No	Parameter	NRECA Mtehod	
		Minimum	**Maximum**
1	*Percent Sub Surface (PSUB)*	0.3	0.9
2	*Ground Water Flow (GWF)*	0.2	0.8
3	*Initial Soil Moisture Storage (ISMS)*	50	200
4	*Initial Ground Water Storage (IGWS)*	2	

3.6 Sensitivity Analysis

Sensitivity analysis is performed by making changes to the input parameters. Each input parameter is tested individually to see its effect on changes in *the* model *output* (Nugroho, 2000). Sensitivity analysis was performed by changing the value of one of the standard or *default* parameters to 25% less than its value (*under-estimate*). The same thing was done again but using parameter values 25% greater than the standard values (*over-estimate*) (Hidayat and Soekarno, 2020) . The concept of sensitivity analysis proposed by (Loucks et al., 1981) states that $Y_0$is *the* nominal *output* of the *default* parameter model, and $Y_{i,L}$and $Y_{i,H}$are the *output* values obtained by increasing or decreasing the value of parameter set $_{-i}$.

Table3 . The Concept of Sensitivity Analysis by (Loucks et al., 1981)

Parameter set	Low Value	Nominal	High value
1	$Y_{1,L}$	Y_0	$Y_{1,H}$
2	$Y_{2,L}$	Y_1	$Y_{2,H}$
3	$Y_{3,L}$	Y_2	$Y_{3,H}$
4	$Y_{4,L}$	Y_3	$Y_{4,H}$

In this study, parameter sensitivity analysis was conducted by increasing and decreasing the parameter percentage by 5%, 10%, 15%, and 20%. Sensitivity assessment was carried out by observing the percentage of the largest *output* deviation by the *underestimate* and *overestimate* parameters when compared to *the output* at the standard parameters.

$$\mathrm{SV} = \frac{|Pu-Ps|}{Ps} x100\%$$

with,

SV = Percentage Deviation (%)

P_u = *output* discharge at *underestimate/overestimate* parameters (m^3 /s)

P_s= *output* discharge at standard parameters *(Q Default)* (m^3/s)

4. Results

Based on the results of the Thiessen Polygon, it is known that the influential stations are Sesaot Station and Jurang Malang Station. The calculation of the average rainfall value for the region was done by multiplying the rainfall data and the Thiessen coefficient from the two influential stations

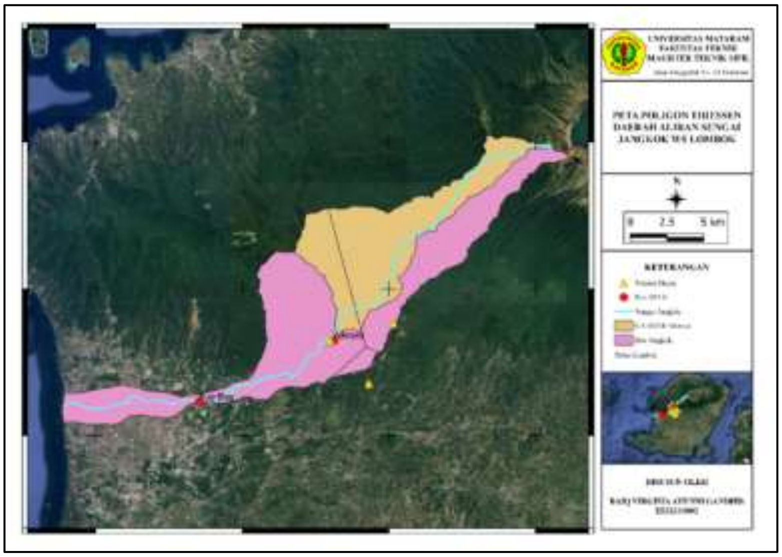


Figure2 . Thiessen Polygon Map of the Jangkok Watershed

4.1 Regional Rainfall

In QGIS, the area of each influential station, namely Sesaot and Jurang Malang, can be determined, with Sesaot Station covering an area of 15.79 km² and Jurang Malang Station covering an area of 49.81 km². Using the area data, the percentage weight of each station can be calculated.

- Thiessen Coefficient for Sesaot Station $= \frac{15,79}{65,60}$ x 100%
  = 24.07%
- Thiessen Coefficient for Jurang Malang Station $= \frac{49,81}{65,60}$ x 100%
  = 75.93%

Example of calculating the average rainfall value for the January 2024 region is done by multiplying the rainfall data and the Thiessen coefficient

$(\bar{R}) = W_1 \; R_1 + W_2 \, R_2$

$= 0.2407 \, (370.30) + 0.7593 \, (257)$

$= 284.27$ mm

Table4 . Average Monthly Rainfall in 2015-2024

No.	Year	Month												Total (mm)
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DES	
1	2015	284.27	320.84	423.03	343.13	209.22	33.93	3.80	10.07	17.54	6.26	282.00	545.76	**2479.83**
2	2016	392.43	433.35	346.90	300.94	406.32	160.65	124.09	56.90	366.87	301.42	509.82	433.91	**2479.83**
3	2017	139.98	440.16	213.33	207.85	433.32	303.67	67.91	21.07	54.80	250.95	440.48	386.61	**3833.60**
4	2018	689.77	242.28	273.93	102.07	92.71	137.54	23.32	9.17	120.07	26.74	698.07	386.28	**2960.11**
5	2019	406.96	242.83	419.99	419.13	43.28	17.46	12.15	0.00	41.00	16.70	161.16	395.79	**2801.93**
6	2020	253.28	343.60	747.37	354.74	142.29	17.43	27.35	85.95	156.08	403.74	523.14	385.88	**2176.46**
7	2021	564.65	559.85	309.40	124.55	241.27	222.96	40.95	242.04	133.37	192.46	605.78	415.31	**3440.83**
8	2022	260.42	509.13	157.14	293.31	191.44	182.68	128.33	21.39	287.43	651.09	383.54	526.56	**3652.58**
9	2023	135.85	332.85	217.87	205.81	62.28	17.39	116.85	0.76	36.32	11.78	404.57	433.22	**3592.48**
10	2024	339.30	253.58	353.18	316.37	169.30	96.94	107.20	2.72	58.04	164.48	491.92	664.90	**1975.54**
Average (mm)		**346.69**	**367.85**	**346.21**	**266.79**	**199.14**	**119.06**	**65.19**	**45.01**	**127.15**	**202.56**	**450.05**	**457.42**	**2939.32**

4.2 AWLR Discharge Data

The AWLR discharge data used as observation discharge for the calibration process in this study is the top AWLR measurement located in the relevant study area, namely the Aiknyet AWLR Station. Based on the schematic diagram of the Jangkok watershed in **Figure 1,** it can be seen that there are no water structures such as dams or reservoirs above the Aiknyet AWLR location that would affect the calculations.

Table5 . AWLR Aiknyet monthly average discharge data for 2015-2024.

No.	Year	Water Discharge (m^3/s)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
1.	2015	3.55	4.14	3.75	3.58	3.16	1.84	0.32	1.25	0.15	0.14	0.46	3.68
2.	2016	2.93	4.50	1.91	3.51	2.41	2.15	1.25	0.54	1.19	4.50	7.27	7.32
3.	2017	3.06	10.57	2.96	3.15	2.13	1.79	1.05	0.43	0.34	1.15	2.92	3.46
4.	2018	6.09	5.04	1.95	1.44	0.74	0.47	0.21	0.16	0.11	0.11	1.75	0
5.	2019	1.58	0.97	1.39	1.45	1.27	0.86	0.72	0.72	0.68	0.67	1.03	1.90
6.	2020	2.49	2.56	3.52	2.92	1.52	1.18	1.13	1.13	2.04	1.00	1.14	2.64
7.	2021	4.58	5.80	3.78	2.49	1.91	2.00	1.88	3.38	3.62	3.44	4.71	3.19
8.	2022	2.61	2.61	1.77	2.53	2.20	2.05	1.50	1.10	1.49	1.00	1.55	3.00
9.	2023	2.63	2.63	2.19	1.58	1.35	0.79	0.79	0.40	0.36	0.32	0.70	2.11
10	2024	1.44	1.16	2.08	2.12	1.27	1.21	0.72	0.58	0.54	0.71	1.80	2.76
Average (m^3/s)		**3.10**	**4.00**	**2.53**	**2.48**	**1.80**	**1.43**	**0.96**	**0.97**	**1.05**	**1.30**	**2.33**	**3.01**

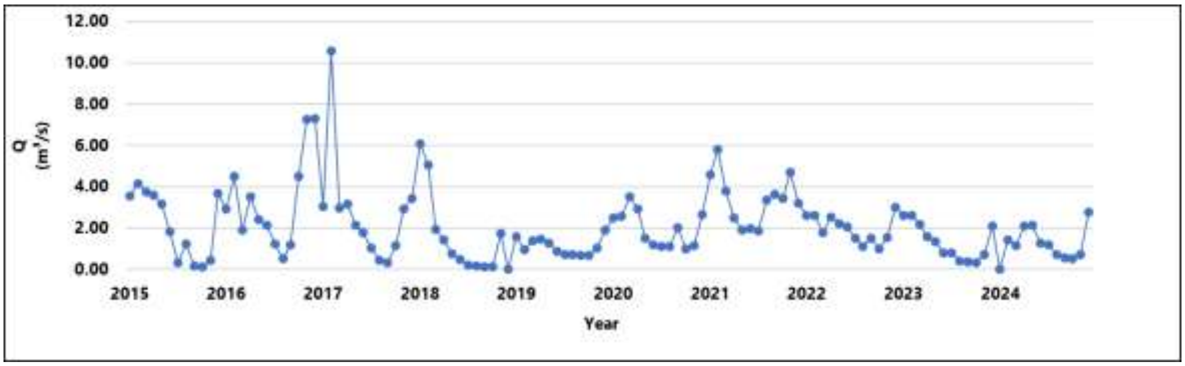


Figure3 . Observation discharge graph for calibration years 2015-2024

4.3 Evapotranspiration Analysis

In the evapotranspiration analysis, the monthly correction factor value for January was obtained as C = 1.10, the value (R_n) = 2.52 mm/day, the temperature and altitude factor (W) was obtained as 0.73, the wind speed function f(U) = 0.98, the actual water vapor pressure (ed) = 23.74 mbar, and the saturated water vapor pressure (ea) for Tc = 22.86°C was obtained as 27.83 mbar. Thus, the potential evapotranspiration for January is as follows.

ETo = $[C (W \times R_n + (1 - W) \times f(U) \times (ea - ed))]$
= $[1.10 ((0.73) \times 2.52 + (1 - 0.73) \times 0.98 \times (27.83 - 23.74))]$
= 3.20 mm/day

ETo = 3.20 × number of days
= 3.20 × 31
= 99.34 mm/month

Table6 . Potential Evapotranspiration

No.	Annotation	Unit	Month											
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
1.	Eto	(mm/day)	3.20	3.27	2.95	2.80	2.92	2.67	2.97	3.72	4.34	4.79	3.73	3.29
2.	Eto	(mm/month)	99.34	91.47	91.54	83.99	90.63	80.14	92.10	115.24	130.35	148.41	111.93	102.08

4.2 Analysis of Rainfall-Runoff Transformation Using the Mock Method

The calibration process for the F.J. Mock method parameters was carried out using the *Excel Solver* tool in Microsoft Excel. The calibration stage was performed on data from 2024, taking into account the Correlation Coefficient (R), *Percentage Error* (PE), *Root Mean Square Error* (RMSE), and *Nash-Sutcliffe Efficiency* (NSE).

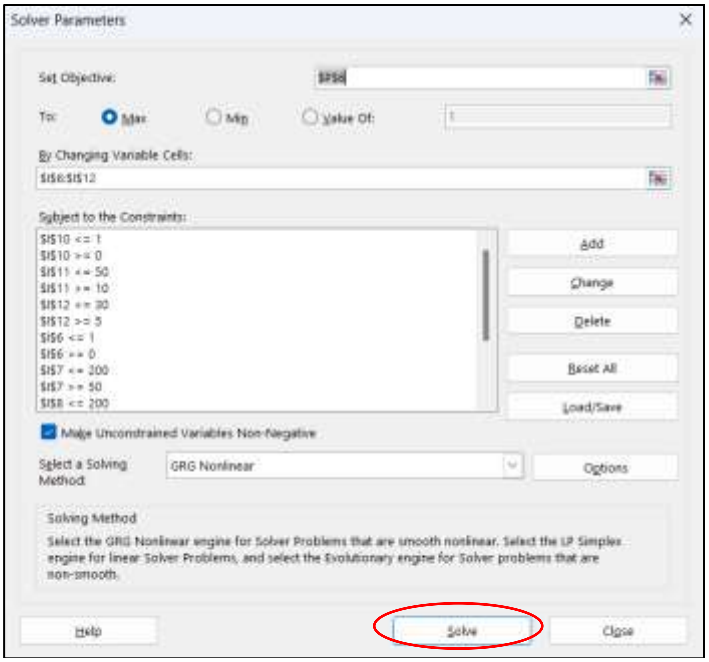


Figure4 . Mock Method calibration using Excel Solver

The calibration process using a solver is carried out with an Objective Function of maximizing the NSE value with Subject to the Constraint input in the form of Mock parameters and their limits. The By Changing Variable Cells column is filled with the parameters to be calibrated. During the calibration stage, the comparison of the simulated discharge to the observed discharge of AWLR Aiknyet takes into account the statistical indicator values that must be met. The calibrated parameters are referred to as default parameters.

Table7 . Mock Method Parameter Calibration Results

No.	Parameter	Calibration Result
1	Infiltration Coefficient	0.83
2	Soil Moisture Capacity	50.00
3	Initial Soil Moisture	50.10
4	Initial Groundwater Storage	1000.00
5	Groundwater Recession Constant	0.98
6	Exposed Surface	16.68
7	Percentage Factor	5.00

The calibrated parameters will produce a new calibration discharge (Q Default) **(Table 7)**. Then, the comparison between the calibration discharge and the AWLR Aiknyet observation discharge is calculated by considering statistical indicators, namely R, PE, NSE, and RMSE **(Figure 5).**

8 . Water availability discharge (QDefault) and parameters (Default Parameter)

Default Parameter	Value	Q Water Availability Discaharge (m^3/s)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
Infiltration Coefficient	0.83												
Soil Moisture Capacity	50.00												
Initial Soil Moisture	50.10												
Initial Groundwater Storage	1000.00	1.261	1.335	1.667	1.682	1.254	0.940	0.915	0.686	0.767	0.861	1.757	3.180
Groundwater Recession Constan	0.98												
Exposed Surface	16.68												
Percentage Factor	5.00												

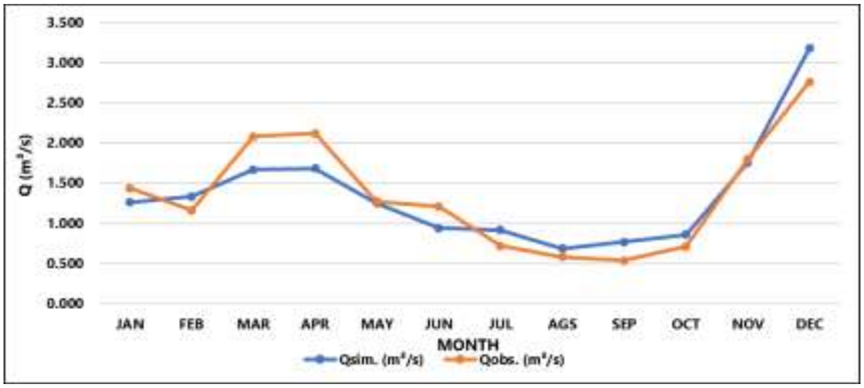


Figure 5 . Comparison Chart of Mock Calibration Results and Observation Discharge in 2024

Based on the data suitability test from the calibration results, it is known that the comparison of the two discharges produces a correlation value of R = 0.92 (≥ 0.75) with a very strong interpretation, PE = 0.01 (≤ 20%), NSE = 0.85 with a very good interpretation, and RMSE = 0.07 with a very accurate interpretation.

4.2 Sensitivity Analysis of Mock Method Parameters

Sensitivity analysis of parameters is performed by increasing (*overestimating*) and decreasing (*underestimating*) the values of calibrated parameters (*default parameters*) one by one while locking the other parameters. Each parameter will be increased by 5%, 10%, 15%, and 20% and decreased by similar values. The following is an example of a 20% overestimate sensitivity analysis for the infiltration coefficient parameter. Based on the calibration results in **Table 6**, the standard (*default*) value of the infiltration parameter is if = 0.83.

1. *Overestimate*
   a. *Overestimate* 20%
      x = *Default* parameter x 20%
      x = 0.83 x 0.2
      x = **0.165424**
      Overestimate parameter value 20%
      = *default* parameter + x
      = 0.83 + **0.165424**
      = **0.99**
2. *Underestimate*
   a. *Overestimate* 20%
      x = *Default* parameter x 20%
      x = 0.83 x 0.2
      x = **0.165424**
      Overestimated parameter value 5%
      = *default* parameter - x
      = 0.83 - **0.165424**
      = **0.66**

The overestimated infiltration coefficient parameter value of 20% = 0.99 was then manually input into the Mock Method calculation in Microsoft Excel to obtain the overestimated water availability discharge for 2024. Next, an analysis of the deviation between the calibrated water availability discharge (*Qdefault*) and the water availability discharge resulting from the 20% *overestimated* infiltration parameter was performed. The overestimated/underestimated parameter values were returned to their default values. The same analysis was performed on six other parameters.

Table9 . Recapitulation of Parameters and Water Availability Discharge Overestimated by 20% Mock Method

Parameter	Value	Q Water Availability Discharge (m^3/s)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
Infiltration Coefficient	0.99	0.492	0.612	0.649	0.761	0.970	0.909	0.889	0.748	0.830	0.921	0.827	1.011
Soil Moisture Capacity	60.00	1.261	1.384	1.670	1.686	1.257	0.944	0.918	0.689	0.770	0.864	1.760	3.183
Initial Soil Moisture	60.12	1.217	1.283	1.660	1.675	1.247	0.934	0.909	0.680	0.760	0.855	1.751	3.174
Initial Groundwater Storage	1200.00	1.344	1.426	1.748	1.764	1.332	1.019	0.990	0.760	0.842	0.932	1.829	3.249
Groundwater Recession Constan	1.00	1.261	1.335	1.667	1.682	1.254	0.940	0.915	0.686	0.767	0.861	1.757	3.180
Exposed Surface	20.02	1.263	1.339	1.665	1.682	1.259	0.946	0.922	0.687	0.768	0.862	1.783	3.180
Percentage Factor	6.00	1.261	1.335	1.667	1.682	1.295	0.965	0.941	0.687	0.781	0.901	1.757	3.180

Table10 . Recapitulation of Parameters and Water Availability Discharge Underestimated by 20% Mock Method

Parameter	Value	Q Water Availability Discharge (m^3/s)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
Infiltration Coefficient	0.66	2.030	2.058	2.685	2.604	1.537	0.971	0.941	0.623	0.703	0.800	2.686	5.349
Soil Moisture Capacity	40.00	1.261	1.287	1.664	1.679	1.250	0.937	0.912	0.683	0.764	0.858	1.754	3.177
Initial Soil Moisture	40.08	1.305	1.388	1.674	1.689	1.260	0.947	0.921	0.692	0.773	0.867	1.763	3.186
Initial Groundwater Storage	800.00	1.178	1.245	1.586	1.600	1.176	0.861	0.840	0.612	0.692	0.789	1.684	3.111
Groundwater Recession Constan	0.79	6.457	6.549	6.118	6.195	5.193	4.223	3.366	2.521	2.119	1.758	2.843	5.459
Exposed Surface	13.35	1.260	1.332	1.669	1.682	1.248	0.934	0.908	0.684	0.765	0.859	1.730	3.181
Percentage Factor	4.00	1.261	1.335	1.667	1.682	1.212	0.916	0.889	0.685	0.752	0.821	1.757	3.180

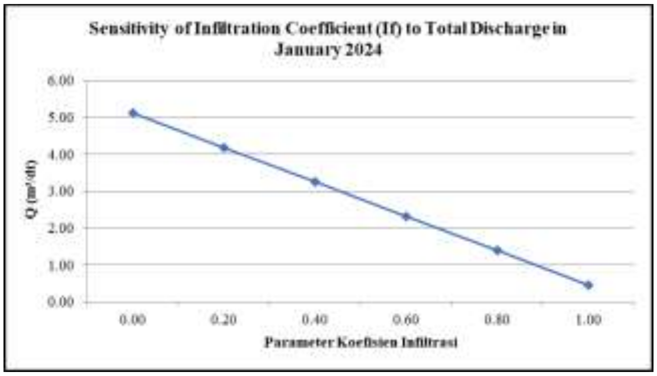
Table11 . Statistical Indicators and Average Difference Overestimate 20% Mock Method

Parameter	Value	Statistical Indicator				
		R	PE	NSE	RMSE	Differences (%)
Infiltration Coefficient	0.99	0.03	0.41	-0.74	0.79	**33.777**
Soil Moisture Capacity	60.00	0.92	0.00	0.85	0.07	0.544
Initial Soil Moisture	60.12	0.92	0.01	0.85	0.07	1.096
Initial Groundwater Storage	1200.00	0.93	0.05	0.84	0.07	**6.763**
Groundwater Recession Constant	1.00	0.92	0.01	0.85	0.07	0.000
Exposed Surface	20.02	0.92	0.00	0.85	0.07	0.374
Percentage Factor	6.00	0.92	0.00	0.85	0.07	**1.290**

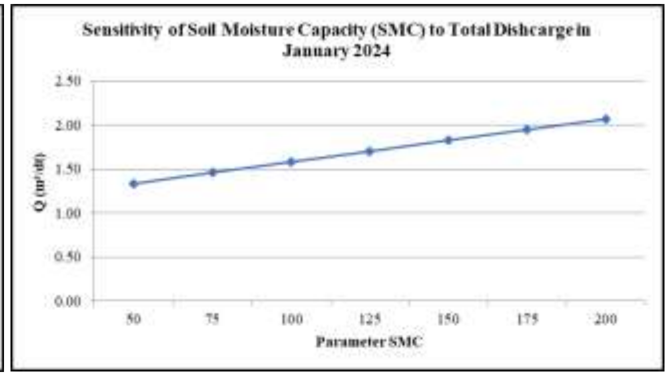
Table12 . Statistical Indicators and Average Difference Underestimate 20% Mock Method

Parameter	Value	Statistical Indicator				
		R	PE	NSE	RMSE	Differences (%)
Infiltration Coefficient	0.66	0.94	0.40	-0.74	0.79	**33.777**
Soil Moisture Capacity	40.00	0.93	0.01	0.86	0.07	0.544
Initial Soil Moisture	40.08	0.92	0.00	0.85	0.07	1.096
Initial Groundwater Storage	800.00	0.92	0.06	0.83	0.08	**6.763**
Groundwater Recession Constant	0.79	0.63	2.22	-23.70	11.19	**245.896**
Exposed Surface	13.35	0.92	0.01	0.85	0.07	0.016
Percentage Factor	4.00	0.93	0.01	0.85	0.07	1.290

To determine the effect of parameter sensitivity on monthly discharge availability and the mock calculation cells it affects, the *input* parameter values were changed one by one with increments according to the limits of each parameter.



(a)



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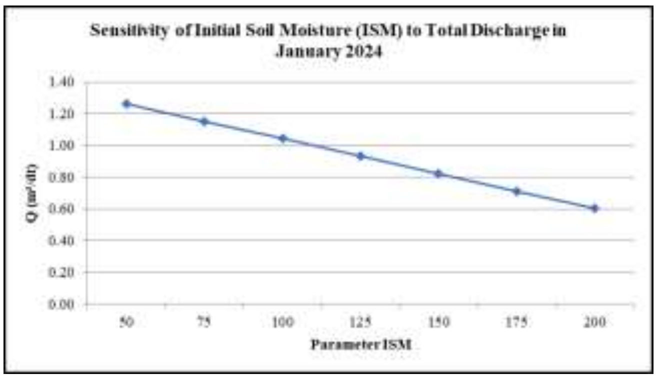

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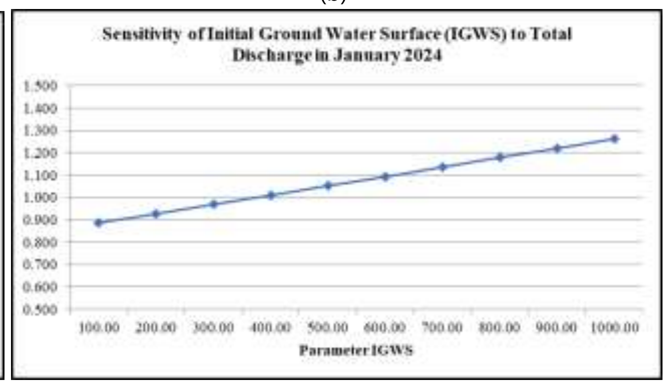

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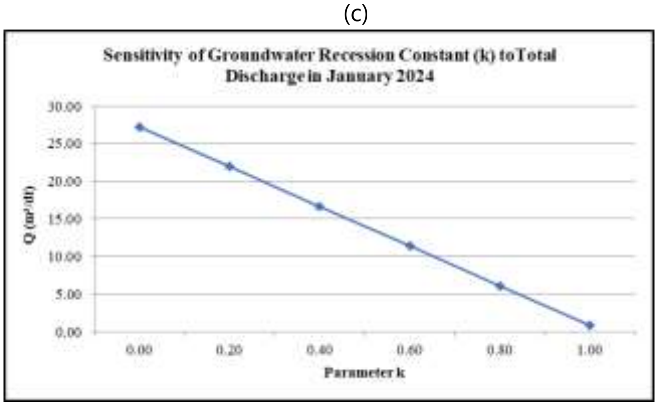
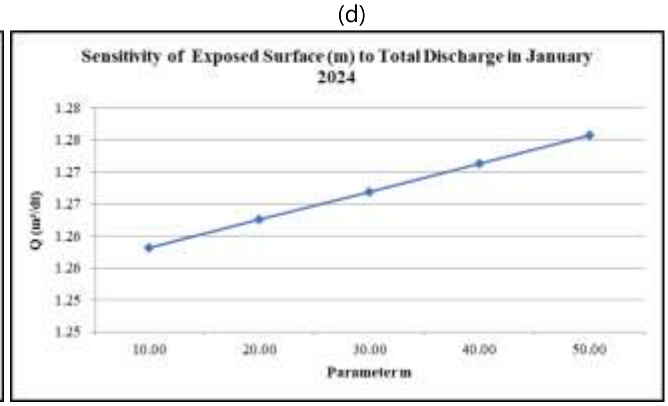
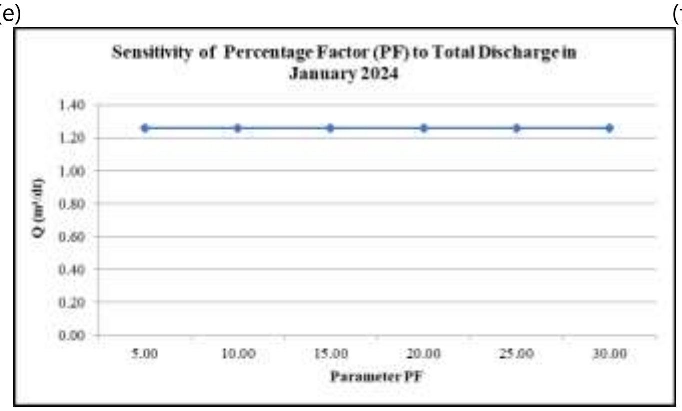


(e)



(f)



(g)

Figure 6 . (a) Sensitivity of Infiltration Coefficient to Flow in January, (b) Sensitivity of SMC to Flow in January 2024, (c) Sensitivity of ISM to Flow in January 2024, (d) Sensitivity of IGWS to Discharge in January 2024, (e) Sensitivity of k to Discharge in January 2024, (f) Sensitivity of m to Discharge in January 2024, (g) Sensitivity of PF to Discharge in January 2024

Figure 6 illustrates the effect of changes in the Mock parameter on monthly discharge in January 2024. This was done as a comparison and proof of whether the parameter is sensitive or not. For the infiltration coefficient, ISM, and k parameters, it is known that the higher the parameter value, the lower the monthly discharge produced. Conversely, for the IGWS, SMC, and m parameters, there is a linear relationship where the higher the parameter value, the higher the monthly discharge produced. Meanwhile, the PF parameter is considered insensitive in January 2024 because any change in the parameter does not result in a change in discharge.

4.3 Rainfall-Runoff Transformation Analysis Using the NRECA Method

At this stage, the same calibration process as in the Mock Method is performed, namely using Excel Solver with Objective Function to maximize the NSE value. In the Subject to the Constraint column, enter the NRECA parameter value and its limits. In the By Changing Variable Cells column, enter the parameters to be calibrated

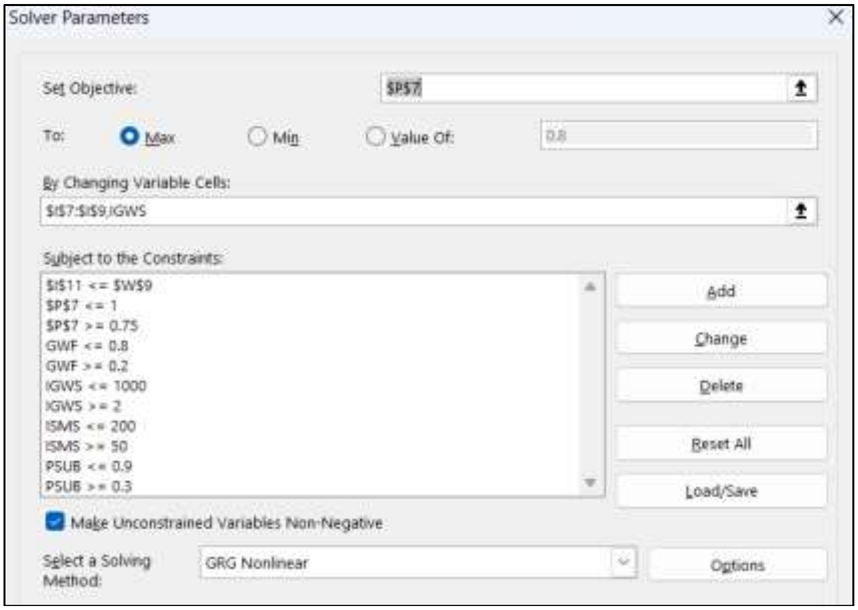


Figure7 . NRECA Method calibration using Excel Solver

Table13 . NRECA Method Parameter Calibration Results

No.	Parameter		Calibration Result
1	Percent Sub Surface	PSUB	0.90
2	Ground Water Flow	GWF	0.20
3	Initial Soil Moisture Storage	ISMS	125.00
4	Initial Groundwater Storage	IGWS	187.57

The calibrated parameters will produce a new calibrated discharge (Q Default) **(Table 13)**. Then, the comparison between the calibrated discharge and the observed discharge of AWLR Aiknyet is calculated by considering statistical indicators, namely R, PE, NSE, and RMSE **(Figure 8).**

Table14 . Water availability discharge (QDefault) and parameters (Default Parameter)

<table>
<tr><th rowspan="2">Default Parameter</th><th rowspan="2">Value</th><th colspan="12">Q Water Availabilty Discharge (m³/s)</th></tr>
<tr><th>JAN</th><th>FEB</th><th>MAR</th><th>APR</th><th>MAY</th><th>JUN</th><th>JUL</th><th>AGS</th><th>SEP</th><th>OCT</th><th>NOV</th><th>DEC</th></tr>
<tr><td>Percent Sub Surface</td><td>0.90</td><td rowspan="4">0.968</td><td rowspan="4">1.110</td><td rowspan="4">1.577</td><td rowspan="4">2.229</td><td rowspan="4">1.834</td><td rowspan="4">1.488</td><td rowspan="4">1.212</td><td rowspan="4">0.945</td><td rowspan="4">0.781</td><td rowspan="4">0.675</td><td rowspan="4">2.260</td><td rowspan="4">4.631</td></tr>
<tr><td>Ground Water Flow</td><td>0.20</td></tr>
<tr><td>Initial Soil Moisture Storage</td><td>125.00</td></tr>
<tr><td>Initial Groundwater Storage</td><td>187.57</td></tr>
</table>

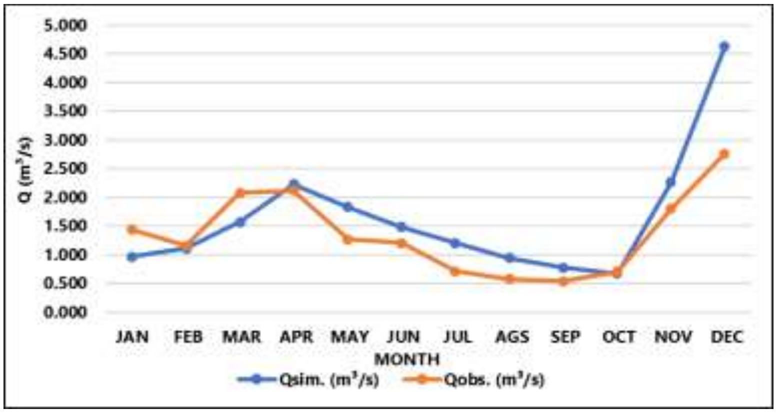


Figure8 . Comparison Chart of NRECA Calibration Results and Observation Discharge in 2024

Based on the data suitability test from the calibration results, it is known that the comparison of the two discharges produces a correlation value of R = 0.85 (≥ 0.75) with a very strong interpretation, PE = 0.20 (≤ 20%), NSE = 0.07 with an unsatisfactory interpretation, and RMSE = 0.42 with a fairly accurate interpretation.

4.2 Sensitivity Analysis of NRECA Method Parameters

Sensitivity analysis of parameters is performed by increasing (*overestimating*) and decreasing (*underestimating*) the values of calibrated parameters (*default parameters*) one by one while locking the other parameters. Each parameter will be increased by 5%, 10%, 15%, and 20% and decreased by similar values. The following is an example of a 20% overestimate sensitivity analysis for the Percent Sub Surface (PSUB) parameter. Based on the calibration results in **Table 11**, the standard (*default*) value of the infiltration parameter is if = 0.90.

1. *Overestimate*

   a. *Overestimate* 20%

      x = *Default* parameter x 20%
      x = 0.90 x 0.2
      x = **0.18**
      Overestimate parameter value 20%
      = *default* parameter + x
      = 0.90 + **0.18**
      = **1.08**

2. *Underestimate*

   a. *Overestimate* 20%

      x = *Default* parameter x 20%
      x = 0.90 x 0.2
      x = **0.18**
      Overestimate parameter value by 5%
      = *default* parameter - x
      = 0.90 - **0.18**
      = **0.72**

Parameter value for 20% overestimation of Percent Sub Surface = 1.08, then manually input into the NRECA Method calculation in Microsoft Excel to obtain the 20% overestimated water availability discharge for 2024. Next, an analysis of the deviation between the calibrated water availability discharge (*Qdefault*) and the water availability discharge resulting from a 20% *overestimate* of the infiltration parameter is performed. The overestimated/underestimated parameter values are returned to their default values. The same analysis is performed on the other three parameters.

Table15 . Recapitulation of Parameters and Water Availability Discharge Overestimated by 20% NRECA Method

Parameter	Value	Q Water Availabilty Discharge (m^3/s)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
Percent Sub Surface	1.08	0.943	0.963	1.185	1.742	1.817	1.653	1.344	1.095	0.905	0.735	1.461	3.143
Ground Water Flow	0.24	1.158	1.262	1.753	2.465	1.993	1.557	1.217	0.901	0.708	0.600	2.396	5.099
Initial Soil Moisture Storage	150.00	0.985	1.166	1.678	2.291	1.904	1.540	1.252	0.976	0.807	0.695	2.358	4.685
Initial Groundwater Storage	225.08	1.152	1.267	1.694	2.326	1.909	1.551	1.260	0.983	0.813	0.700	2.281	4.647

Table16 . Recapitulation of Parameters and Water Availability Discharge Underestimated by 20% NRECA Method

Parameter	Value	Q Water Availability Discharge (m^3/s)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
Percent Sub Surface	0.72	0.993	1.257	1.968	2.715	1.851	1.324	1.080	0.794	0.656	0.615	3.060	6.119
Ground Water Flow	0.16	0.778	0.942	1.376	1.957	1.628	1.366	1.157	0.946	0.821	0.729	2.113	4.143
Initial Soil Moisture Storage	100.00	0.952	1.053	1.475	2.100	1.752	1.421	1.160	0.903	0.746	0.648	2.319	4.654
Initial Groundwater Storage	150.05	0.784	0.953	1.459	2.132	1.759	1.426	1.164	0.906	0.749	0.650	2.240	4.616

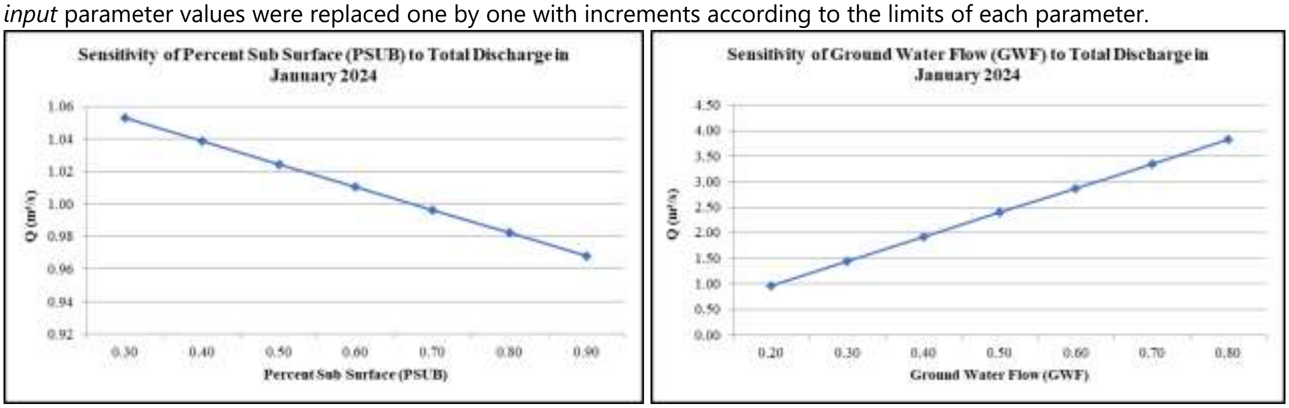
Table17 . Statistical Indicators and Average Difference Overestimate 20% NRECA Method

Parameter	Value	Statistical Indicator				
		R	PE	NSE	RMSE	Differences (%)
Percent Sub Surface	1.08	0.73	0.04	0.49	0.23	**16.14**
Ground Water Flow	0.24	0.87	0.29	-0.32	0.60	9.16
Initial Soil Moisture Storage	150.00	0.85	0.24	0.00	0.45	3.49
Initial Groundwater Storage	225.08	0.86	0.26	0.06	0.43	5.86

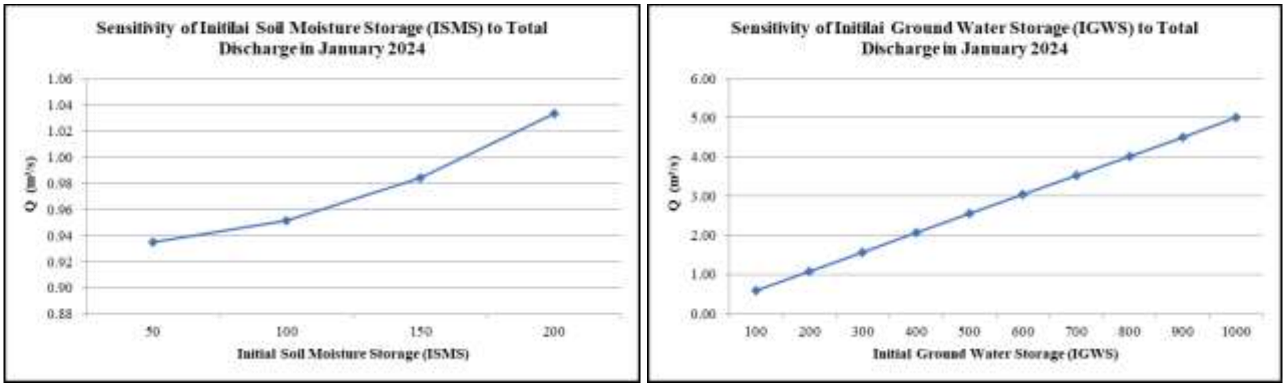
Table18 . Statistical Indicators and Average Difference Underestimate 20% NRECA Method

Parameter	Value	Statistical Indicator				
		R	PE	NSE	RMSE	Differences (%)
Percent Sub Surface	0.72	0.87	0.37	-1.57	1.17	**20.08**
Ground Water Flow	0.16	0.82	0.10	0.34	0.30	9.51
Initial Soil Moisture Storage	100.00	0.84	0.17	0.06	0.42	4.01
Initial Groundwater Storage	150.05	0.83	0.15	0.06	0.43	5.86

To determine the effect of parameter sensitivity on monthly discharge availability and the NRECA calculation cells that it affects, the *input* parameter values were replaced one by one with increments according to the limits of each parameter.



(a) (b)



(c) (d)

Figure9 . (a) Sensitivity of Percent Sub Surface to Flow in January, (b) Sensitivity of GWF to Flow in January 2024, (c) Sensitivity of ISMS to Flow in January 2024, (d) Sensitivity of IGWS to Flow in January 2024

Figure 9 illustrates the effect of changes in the NRECA parameter on monthly discharge in January 2024. This was done as a comparison and proof of whether the parameter is sensitive or not. For the PSUB parameter, it is known that the higher the parameter value, the lower the monthly discharge produced. Conversely, the GWF and ISMS parameters produce a linear relationship where the higher the parameter value, the higher the monthly discharge produced. However, it can be seen that the ISMS parameter has a flatter graph, indicating that ISMS has lower sensitivity compared to other parameters.

5. Conclusion

Based on the results of this study, it is known that in the Mock Method, the largest change in water availability discharge is produced in *Overestimate* and *Underestimate* conditions of 20%. Under *Overestimate* conditions, the most sensitive parameter was the Infiltration Coefficient. The Infiltration Coefficient parameter value was 0.99, with a change in discharge in January 2024 from 1.261 m^3/dt to 0.492 m^3/dt, resulting in an average deviation of 33.78%. This was followed by the *Initial Groundwater Storage* (IGWS) parameter of 1200 with a change in discharge in January 2024 from 1.261 m^3/dt to 1.344 m^3/dt, resulting in an average deviation of 6.76%. Next, the *Percentage Factor* (PF) parameter produced an average deviation of 1.29%. Meanwhile, other parameters, namely SMC, ISM, m, and k, were considered less sensitive because they produced a low deviation percentage of less than 1%. Under the *Underestimate* condition, the most sensitive parameter is the *Groundwater Recession Constant* (k) parameter. The k parameter value obtained is 0.79 with a discharge change in January 2024 from 1.261 m^3/dt to 6.457 m^3/dt, resulting in an average deviation of 245.89%. This is followed by the Infiltration Coefficient parameter of 0.66 with a change in discharge in January 2024 from 1.261 m^3/dt to 2.030 m^3/dt, resulting in an average deviation of 33.77%. Next, the IGWS parameter was 800 with a change in discharge in January 2024 from 1.261 m^3/dt to 1.178 m^3/dt, resulting in an average deviation of 6.76%.

In the NRECA method, the largest change in water availability discharge is produced by the *Percent Sub Surface* (PSUB) parameter in both the *20% overestimate* and *20% underestimate* conditions. Under a 20% *overestimate* condition, the PSUB parameter value is 1.08, with a change in discharge in January 2024 from 0.968 m^3/dt to 0.943 m^3/dt, resulting in an average deviation of 16.14%. This was followed by the *Ground Water Flow* (GWF) parameter of 0.24 with a change in discharge in January 2024 from 0.968 m^3/dt to 1.158 m^3/dt, resulting in an average deviation of 9.16%. Under an *underestimate* condition of 20%, the PSUB parameter value was 0.72 with a discharge change in January 2024 from 0.968 m^3/dt to 0.993 m^3/dt, resulting in an average deviation of 20.08%. This was followed by the GWF parameter of 0.16 with a change in discharge in January 2024 from 0.968 m^3/dt to 0.778 m^3/dt, resulting in an average deviation of 9.51%.

Based on **Table 11** and **Table 17**, it can be seen that parameters that produce large changes in discharge also produce large average deviations. The higher the average deviation produced, the higher the sensitivity of the parameter. The higher the sensitivity of the parameter, the lower the correlation (R) and NSE values and the higher the PE and RMSE values. In this case, in the Mock method, the parameters that produce the highest sensitivity are the infiltration coefficient parameter in the 20% overestimate condition and the k parameter in the 20% underestimate condition. Meanwhile, in the NRECA method, the parameter that produces the highest sensitivity is the PSUB parameter ( ) in both the 20% overestimate and 20% underestimate conditions. These three parameters can have the greatest impact on changes in water availability flow. Therefore, monitoring and control of these parameters are necessary.

Funding: This research received no external funding
Conflicts of Interest: The authors declare no conflict of interest.
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