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STUDY OF THE INTERCONNECTION OF PIT LAKES TO FULFILL RAW WATER NEEDS IN UNDERDEVELOPED AREAS IN BANGKA DISTRICT

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ABSTRACT: Pit lakes, known locally as *kolong*, are formed from abandoned open-pit mining areas that fill naturally with runoff and groundwater. In Bangka Regency, Sumatra, many communities rely heavily on groundwater from bore wells to meet their raw water needs. However, these sources often experience shortages during prolonged dry seasons. This study aims to explore the potential utilization of Kolong Dam 1 Pemali and Kolong Simpur Pemali as alternative raw water sources through an interconnection system to improve water supply reliability in rural areas, particularly in Pemali District. Bias correction of satellite rainfall data was conducted using the quantile mapping method, significantly increasing the accuracy of precipitation data. Water availability was analyzed using the NRECA method, and future water demand was projected over a 20-year period (2024–2044). Two operational scenarios were simulated: the first, using only Kolong Dam 1 Pemali, failed to meet demand during dry seasons, showing a 91.3% reliability rate. The second, with an interconnected system between both kolong, significantly improved performance, achieving a 97.2% reliability rate. The findings demonstrate that interconnecting kolong provides a technically feasible and effective solution to enhance the reliability of water supply systems in Bangka, especially during seasonal fluctuations in water availability.

Keywords: Raw water, Interconnection, Satellite data, Operation pattern, Kolong

1. INTRODUCTION

Pit lakes or *kolong* (Fig. 1), a local term for mine pits in general, are formed when open-pit mining activities have ceased operations or have been abandoned. These former mining pits become filled with runoff and groundwater [1]. Kolong have characteristics originating from mining activities, such as depth, width, and lake volume [1–3]. The catchment area of kolong is usually small. The depth of the kolong is related to the water balance between inflow and outflow, which reaches stability after several years to decades [4].

The Bangka Belitung Islands have the potential of natural resources as the largest tin producer in Indonesia. Several cities in the Bangka Belitung Islands utilize water sources from long-abandoned kolong. According to the 2022 Rencana Induk Sistem Penyediaan Air Minum (RISPAM) or Master Plan for the Drinking Water Supply System of the Bangka Province, communities in Bangka Regency generally meet their raw water needs by utilizing groundwater through bore wells. This indicates that the community still relies on groundwater for water supply, especially in areas not yet reached by the Sistem Penyediaan Air Minum (SPAM) or Drinking Water Supply System. However, the availability of water in these wells is often limited during prolonged dry seasons. Therefore, the development of Perusahaan Daerah Air Minum (PDAM) or Local Government-Owned Water Utility Tirta Bangka becomes an alternative to fulfill water needs.

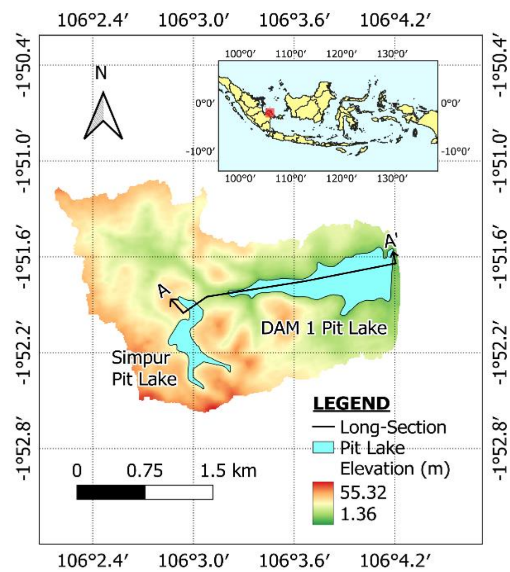

Fig. 1 Pit Lakes (Kolong)

The Bangka Regency Government, PDAM Tirta Bangka, and Balai Wilayah Sungai (BWS) or River Basin Organization (RBO) Bangka Belitung have plans to utilize Kolong Dam 1 Pemali and Kolong Simpur Pemali to meet the raw water needs in rural areas, particularly in Pemali District. The utilization of these kolong aligns with the 2022 Bangka Belitung River Basin Planning Pattern under the topic of Water Resources Utilization. Points outlined in the plan include: the unmet raw water needs in rural areas, the lack of water provision for industry and development zones, and the suboptimal development and maintenance of infrastructure for water needs.

Therefore, the objective of this study is to explore the potential utilization of kolong in Bangka Regency through the development of an interconnected operational system. This initiative aims to enhance the resilience and sustainability of raw water supply, particularly in underserved or disadvantaged areas that are highly vulnerable to water shortages during dry seasons. By integrating multiple kolong, the study seeks to provide a more reliable and efficient alternative water source to support local communities.

This study integrates bias correction for satellite rainfall data, water availability modeling, and projections of future water demand for kolong operational pattern. Two calculation methods, probabilistic and stochastic, are used to evaluate the performance of the kolong system before and after interconnection. This comprehensive and data-driven approach not only contributes to the limited literature on kolong utilization but also offers a simple yet practical analytical framework for systematically, effectively, and efficiently developing kolong operation schemes.

2. RESEARCH SIGNIFICANCE

The significance of this research lies in its potential to address the critical issue of water scarcity in rural areas where water sources can be difficult to obtain. The study explores the possibility of utilizing long-abandoned mining pits (kolong) to meet the growing demand for raw water, which is especially crucial during dry seasons when groundwater availability becomes insufficient. By investigating the potential of kolong, the research aims to provide a sustainable and alternative source of water that can support the local population's needs. Additionally, the research's focus on interconnecting kolong operations could lead to more efficient and integrated water management systems, helping to address water shortages in both rural communities and industries. The findings could also inform future policies on water resource management and the optimization of abandoned mining sites for community benefit, contributing to the long-term development and well-being of the Bangka Regency region.

3. STUDY LOCATION

The locations of Kolong Dam 1 Pemali and Kolong Simpur are in Pemali Village, Pemali District, Bangka Regency. Based on the geographical location of Pemali District, the total area of Pemali District is 127.87 km², which consists of six villages: Penyamun Village with an area of 41.00 km², Pemali Village with an area of 9.88 km², Air Duren Village with an area of 7.65 km², Air Ruai Village with an area of 11.58 km², Karya Makmur Village with an area of 3.52 km², and Sempan Village with an area of 54.25 km². The six villages are the primary targets in the raw water distribution plan from kolong, considering their location within Pemali District and the relatively high demand for water. Once the raw water needs of these six villages are optimally met, the next phase of the distribution development will be directed toward neighboring areas, specifically Sungailiat District (Fig. 2), as part of the expansion of raw water supply services coverage.

According to data from the Central Statistics Agency of Pemali District in the 2022 Statistical Yearbook, the population is 34,950 people. The highest population is in Air Ruai District, with 9,384 people, while the lowest population is in Sempan District, with 3,952 people. The population density in Pemali District tends to increase along with the rise in population.

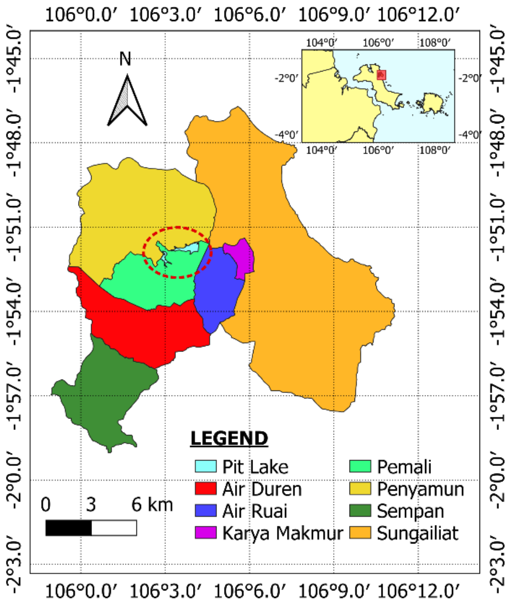

Fig. 2 Targeted raw water distribution area

4. METHODOLOGY

The research framework in

Fig. 3 illustrates how the increasing scarcity of water requires solutions to meet water demand. At the study site, there is a kolong that can be utilized as a water storage facility. Therefore, an analysis is needed to determine the current water demand, followed by a projection of future water needs. In addition to assessing demand, it is essential to analyze the availability of water from rainfall that can be captured within the kolong capacity. Following this, an evaluation of the kolong operation scheme is necessary to manage the inflow and outflow of water effectively, ensuring optimal usage and sustainability of the resource.

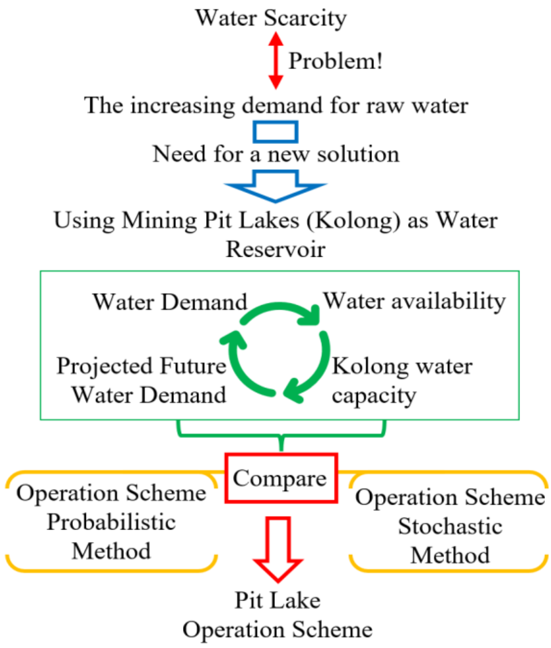

Fig. 3 Research Conceptual Work

4.1 Data Description

4.1.1 Storage Curve

The storage curve shows the relationship between elevation and water level, as well as the storage volume. In this study, the elevation-storage curve was derived using topographic data from the National Digital Elevation Model (DEMNAS) to support volumetric and area analysis (Fig. 4).

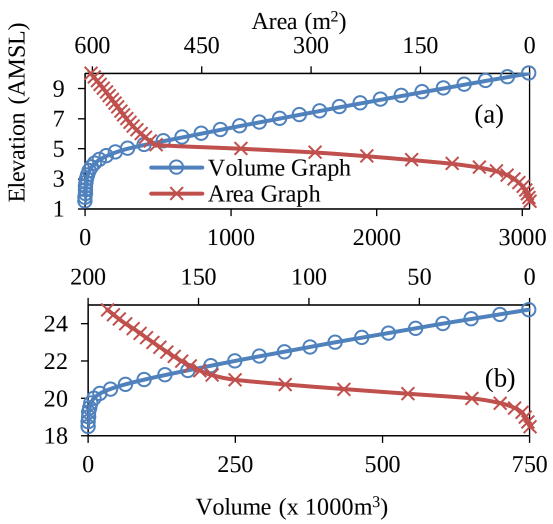

Fig. 4 Storage curve of (a) Dam 1 (b) Simpur

4.1.2 Soil Hydrological Data

The Hydrologic Soil Group (HSG) data for each area has various classifications, resulting in different tendencies for rainfall to generate runoff. In the study area, the watershed at kolong is classified as HSG-D. This indicates that the soil conditions in the area have a low infiltration capacity.

4.1.3 Hydro-climatology Processing

The analysis of potential evapotranspiration requires meteorological data, including humidity, duration of sunlight, average temperature, and average wind speed. In this study, these data were obtained from the Dipati Amir Meteorological Station. The recorded air temperatures ranged from 26.1°C to 27.5°C, with an average of 26.9°C. Wind speeds varied between 1.9 and 3.8 m/s, averaging 2.7 m/s. Sunlight duration ranged from 2.7 to 6.7 hours per day, with a daily average of 4.9 hours, while relative humidity ranged from 78% to 88%, with an average of 83.4%.

The rainfall station was selected using the Thiessen polygon method, with Sungailiat Station identified as the most representative for the study area. This station provides daily rainfall data spanning from 2021 to 2023. Due to limited data availability, the Sungailiat Station was used as a reference for bias correction of satellite rainfall data.

Satellite rainfall data were sourced from the Global Precipitation Measurement Mission (GPM), accessible at (giovanni.gsfc.nasa.gov/giovanni). Bias correction of the GPM data was performed using the quantile mapping method with observed rainfall data [5]. This method is widely adopted due to its simplicity and effectiveness in reducing variability between observed and simulated data for both rainfall and temperature. A bias correction was applied using the Quantile Mapping method, which involves constructing percentile distributions for both datasets and determining appropriate correction factors through a comparative analysis [6].

4.2 Evapotranspiration

Evapotranspiration is a critical parameter in the calculation of the water balance for a reservoir [7]. In this study, evapotranspiration was estimated using the Penman-Monteith equation [8–11] as follows.

$$ET_o = \frac{0.408\Delta R - R_n + \gamma \frac{900}{(T+273)} U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\, U_2)} \tag{1}$$

Where in Eq.(1), ET_o represents potential evapotranspiration (mm/day), R_n is the net solar radiation (mm/day), and T denotes the average temperature (°C). U_2 refers to the average wind speed at a height of 2 meters (m/s), while e_s and e_a are the saturated and actual vapor pressures (kPa), respectively. Δ is the slope of the vapor pressure curve with respect to temperature (kPa/°C), and γ is the psychrometric constant (kPa/°C).

4.3 Water Availability

The Natural Rural Electrical Cooperation Agency (NRECA) method is a technique introduced by Normal H. Crawford to estimate river flow in a watershed [12–14]. The flow reliability for probability operation scheme was set at 35% for wet years, 50% for normal years, 65% for dry years, and 90% for maintenance flow. Broadly, the NRECA method is based on the following assumption.

$$Q = R - E + \Delta S \tag{2}$$

Where Q represents runoff discharge (mm), R is the rainfall (mm), E denotes evapotranspiration (mm), and ΔS refers to the change in soil water content (mm).

4.4 Water Demand

Drinking water demand, for both domestic activities (such as households) and non-domestic activities (including industry, offices, educational facilities, and other public services), is a crucial aspect that needs to be met daily in terms of both quantity and quality. Meeting this demand supports the sustainability of life, public health, economic growth, and regional development [13]. In terms of quantity, drinking water demand is influenced by various factors, including the standard of living, activity intensity, economic development level, and population density in a region [15,16]. The growth of the industrial and service sectors also significantly contributes to the increasing water demand, as production and operational processes require large amounts of raw water. To meet the raw water needs, it is essential to consider future water demand, requiring the analysis of population projections [17]. For population projection, data on population numbers over the past 10 years is necessary. Population projections can be calculated using geometric [18], arithmetic [19,20], or least squares methods [21–24]. In these three equations, P_n represents the population in year n, the targeted year to be projected into, P_o is the initial population, d_n is the time period, and r is the average annual population growth rate.

Geometric Method: $P_n = P_o(1+r)^{dn}$ (3)

Arithmetic Method: $P_n = P_o + r(dn)$ (4)

Least Square Method: $P_n = a + (bt)$ (5)

Where t represents the additional years counted, a and b can be calculated as follows respectively [21–24] :

$$a = \frac{(\Sigma p)(\Sigma t^2) - (\Sigma t)(\Sigma p.t)}{n(\Sigma t^2) - (\Sigma t)^2} \tag{6}$$

$$b = \frac{n(\Sigma p.t) - (\Sigma t)(\Sigma p)}{n(\Sigma t^2) - (\Sigma t)^2} \tag{7}$$

Based on the Technical Guidelines for SPAM Design Planning, non-domestic water service is calculated based on the Master Plan for SPAM in the Bangka Belitung Islands Province, with an approach of 20-30% of domestic water service.

4.5 Kolong's Operation Scheme

Kolong operation refers to activities aimed at regulating the water balance between incoming and outgoing water. The water management can be calculated using the reservoir optimization equation [25–29] as follows:

$$S_{t+1} = S_t + I - E - W \tag{8}$$

Where S_{t+1} represents the storage at the end of the month (m³), S_t is the storage at the beginning of the month (m³), I is the inflow to the reservoir (m³), E is the evaporation from the reservoir surface (m³), and W is the water overflow from the spillway (m³).

In reservoir operation schemes, two primary approaches are commonly used: the probabilistic method and the stochastic method. The probabilistic approach focuses on ensuring that the reservoir can meet raw water demands under various hydrological conditions, including dry, normal, and wet seasons in the future. In contrast, the stochastic approach evaluates the long-term reliability of the reservoir in supplying raw water by taking into account the uncertainty and variability of inflows over time, based on historical inflow data [30-32].

The probabilistic method offers an approach to reservoir operation analysis by first categorizing water availability into three probability levels: 35%, 50%, and 65%, as previously explained in the earlier subsection. This classification is based on probabilistic quartile divisions, where a 35% probability is considered the upper operational limit, representing wet year scenarios, while a 65% probability reflects the lower operational limit typical of dry years. The 50% probability corresponds to normal conditions. This method is commonly used in Indonesia to define reservoir operation scheme, thereby supporting more adaptive and reliable reservoir management. While the stochastic method is also used for defining reservoir operation scheme by considering historical data. Fig. 5 illustrates the difference between these two approaches, highlighting their distinct characteristics.

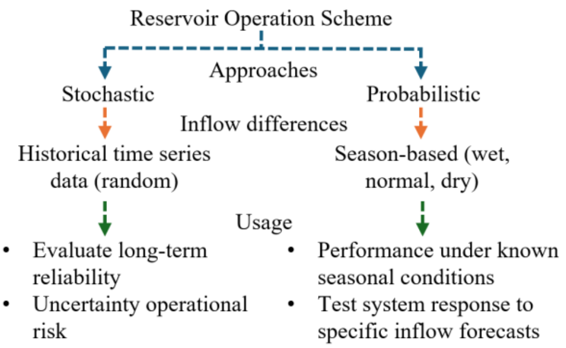

Fig. 5 Differences approaches operation scheme

5. RESULT AND DISCUSSION

5.1 Bias Correction of Satellite Rainfall Data

In this study, rainfall data filling is performed using the quantile mapping method, which involves dividing the rainfall data into several quartiles, sorting them from highest to lowest, and then determining the correction factor for each quartile.

The correction factors obtained through the quantile mapping method are then multiplied by the satellite rainfall values for each quartile. This process aims to reduce bias and produce more accurate and representative rainfall data that reflects the actual field conditions.

The corrected rainfall data is then evaluated using several statistical parameters, namely root mean square error (RMSE), R-Squared (R^2), and correlation (R), to assess the compatibility between the corrected satellite rainfall data and the station rainfall data.

The evaluation results, shown in

Fig. 6 indicate that the corrected GPM data has a very high degree of agreement with the observed rainfall data. Based on the statistical results, the RMSE decreased from 16.76 to 1.53, R^2 increased from 0.977 to 0.995, and R improved from 0.989 to 0.997. These statistical results demonstrate that the corrected satellite rainfall data has good accuracy.

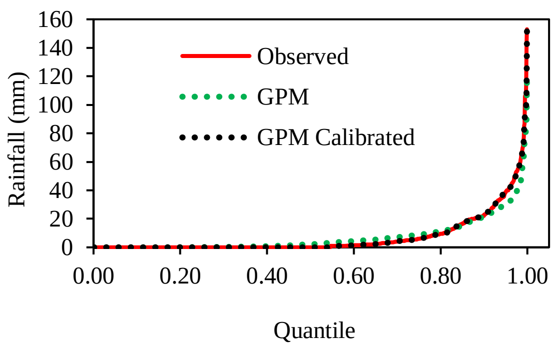

Fig. 6 Comparison between observations and satellite data

5.2 Water Availability

The NRECA method parameters were set based on the Hydrologic Soil Group (HSG) map, identifying the soil as low sand and high clay content. The Percolation to Subsurface Baseflow (PSUB) and Groundwater Flow Factor (GWF) were assumed impermeable, valued at 0.4 and 0.7. Using these values, discharge from 2002–2023 was modeled. Evapotranspiration, calculated with Eq.(2), provided monthly average daily rates and was used to estimate evaporation losses from the kolong.

The available discharge model result shown in Fig. 7 shows that available discharge into Dam 1 is higher than Simpur. Reliable flow analysis for dry, normal, and wet seasons was based on the flow duration curve percentiles—65%, 50%, and 35% respectively—reflecting typical hydrological study practices for Kolong Dam 1 (Fig. 8) and Kolong Simpur (Fig. 9).

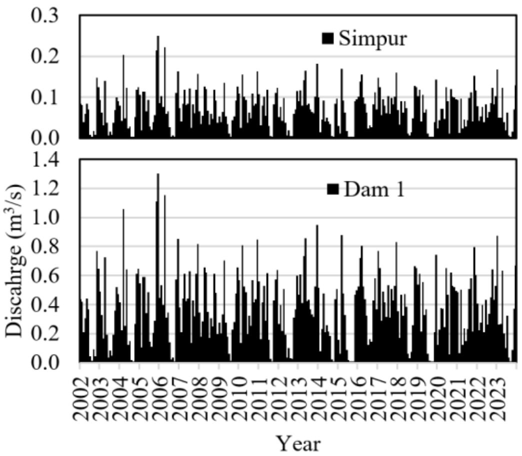

Fig. 7 Available discharge in each kolong

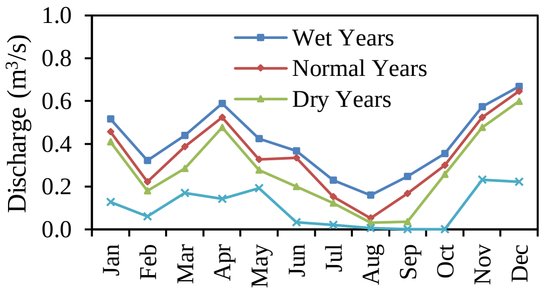

Fig. 8 Reliable discharge of Kolong Dam 1

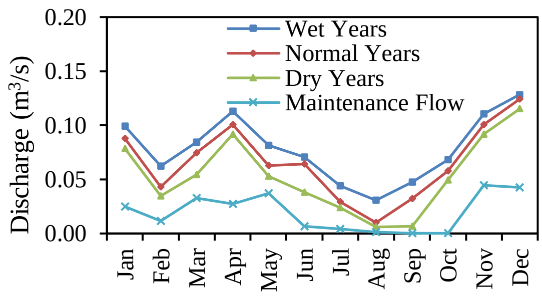

Fig. 9 Reliable discharge in Kolong Simpur

5.3 Water Demand

The new SPAM development is projected over a 20-year period (2024–2044), targeting 100% service coverage in Pemali District. Any surplus discharge will be utilized for other district. Population growth projections for Pemali will be detailed by village, as it is the primary focus of this study.

Table 1. Water Demand Recapitulation

Location	Demand (L/s)
Air Ruai Village	97.63
Karya Makmur Village	28.02
Penyamun Village	20.41
Sungailiat Sub-district	99.68
Pemali Village	18.119
Air Duren Village	11.106
Sempan Village	14.417
Maintenance Flow	15
Demand Total	304.38

Analysis in Table 1 indicates that the geometric method, suitable for areas with exponential population growth, is predominantly applied in Penyamun Village, Pemali Village, Air Ruai Village, and Sungailiat Subdistrict. The arithmetic method is used for Karya Makmur and Sempan Villages, while the least squares method is applied to Air Duren Village.

5.4 Operation Scheme

The probabilistic pit operation scheme at Kolong Dam 1 Pemali was designed by considering inflow variations based on annual climate conditions. The flow reliability was set at 35% for wet years, 50% for normal years, and 65% for dry years. This approach allows water management adjustments to meet higher demands during wet years and adapt to dry, normal, and wet seasons.

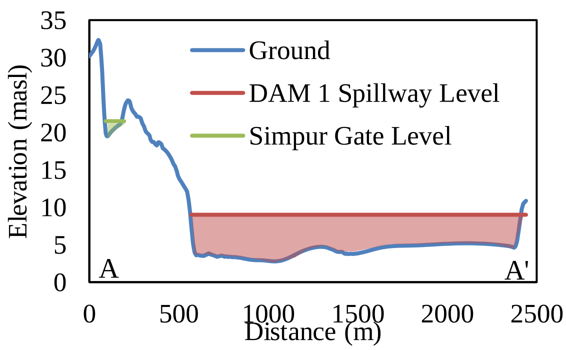

Fig. 10 Kolong long section refers to Figure 1

The outflow was calculated based on estimated raw water demands, ensuring efficient and sustainable water resource management throughout the year. The bottom elevation and maximum water surface elevation of the pits analyzed were key parameters in evaluating storage capacity and interconnection potential between pits.

Fig. 10 is a long section taken from Fig. 1 A – A' line showing the interconnection of kolong, shows that Kolong Simpur Pemali has a bottom elevation of +19.5 meters and a gate at +21.5 meters. Meanwhile, Kolong Dam 1 Pemali has a lower bottom elevation of +5.5 meters, with a spillway at +9.0 meters and an intake at +5.5 meters. This elevation difference offers technical potential for a gravity-based interconnection system, with Kolong Simpur Pemali serving as a backup water supply and Kolong Dam 1 Pemali acting as the receiving pit, especially during dry season deficits. This supports the strategy of interconnecting pits to enhance water supply reliability in the study area.

The probabilistic and stochastic analysis was conducted under two scenarios to meet development water demands, considering pit operation scheme performance before and after interconnection. First the probabilistic analysis. The first scenario (Fig. 11) involved a development water demand of 304.48 L/s, sourced solely from Kolong Dam 1 Pemali (Fig. 10). Simulation results showed that during normal and wet years, the water supply could meet the demand, but during the dry years, supply failure occurred, as indicated by an inability to return to initial storage levels. This showed that Kolong Dam 1 Pemali alone could not meet the development water demand during the dry years.

In the second scenario (

Fig. 12), water was sourced from both Kolong Dam 1 Pemali and Kolong Simpur Pemali, connected through an interconnection system (Fig. 10). Based on the simulated operation scheme, the interconnection successfully met the development water demand of 304.48 L/s continuously across all three scenarios and conditions. This demonstrates that the interconnection strategy can significantly improve water supply reliability under a probabilistic operation scheme.

A stochastic operation was then carried out using discharge time series data from 2002 to 2023 to determine the reliability and how long impounding at Kolong Dam 1 Pemali would be necessary. The stochastic simulation was conducted at a one-month interval from 2002 to 2023. If the water availability in the pit was insufficient during withdrawal, indicated by the water surface level being lower than the intake elevation (+5.5m), the pit was refilled, resulting in zero withdrawal (0 m³/s) for that month. The simulation over a 252-month period provided a comparison of system performance before and after interconnection shown in Fig. 11 and

Fig. 12. In the pre-interconnection scenario (Fig. 11), there were 22 months of pit refilling (unmet

demand), indicating disruptions in the continuity of water supply. This resulted in a withdrawal success rate of 91.3%, showing that the system was not yet optimal in meeting demands throughout the simulation period. In contrast, the post-interconnection scenario (

Fig. 12) showed significant improvement, with only 7 months of pit refilling during the same period. This reflects an increase in efficiency and reliability of the water supply system, as indicated by the improved withdrawal success rate of 97.2%. The drastic reduction in the number of months requiring pit refilling demonstrates that interconnection has a positive impact on enhancing the system's adaptive capacity to variations in water availability.

The reservoir operation simulation shows that without interconnection, the water level drops drastically during the dry years and approaches the minimum elevation, when this happen it indicates that kolong would be unable to meet the water demand. Conversely, interconnecting the kolong helps maintain a stable water level throughout the year and improves the reliability of the water supply. Fig. 11 and Fig. 12 show the results of both reservoir operation methods, by comparing these two methods, it can be observed that the analysis using the stochastic method, when compared with the probabilistic method, represented by graphs for wet, dry, and normal year scenarios, shows that reservoir operations in certain years tend to fall within the range defined by the wet, normal, and dry boundaries. This comparison highlights how the stochastic approach aligns with the operational patterns outlined in the probabilistic framework. Fig. 12 also shows the interconnection model reveals that the stochastic approach has a reliability rate of 97.2% over the 252-month simulation period. This indicates that while the stochastic method helps determine how frequently the kolong need to be refilled, the probabilistic approach produces a more conservative operation result. The kolong operation system has the potential to meet the water needs of the study area, contingent upon the establishment of an effective downstream water allocation system, particularly during dry years and in response to growing demand pressures.

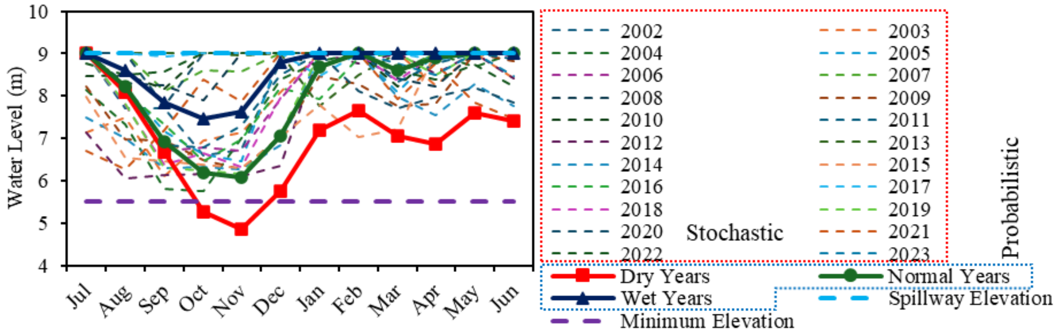

Fig. 11 Stochastic and probabilistic operation scheme before interconnection

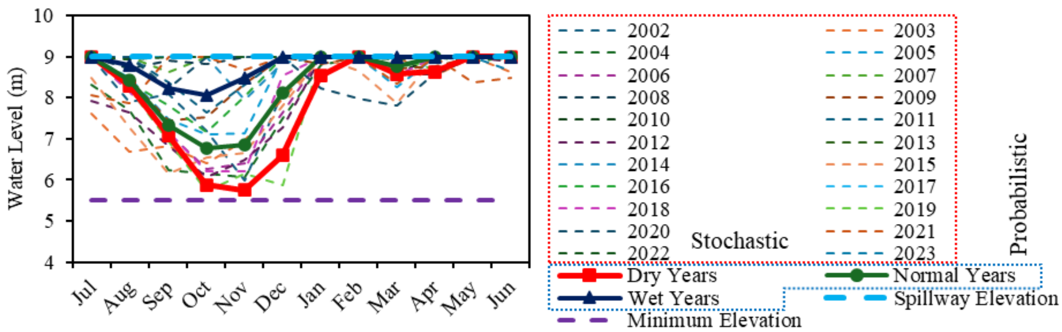

Fig. 12 Stochastic and Probabilistic operation scheme after interconnection

6. CONCLUSION

This study analyzes the reliability of the water supply system based on two scenarios involving the use of water resources from Kolong Dam 1 Pemali and Kolong Simpur Pemali. In the first scenario, with an increased demand of 304.48 L/s, Kolong Dam 1 Pemali failed to meet the water supply during the dry season, as indicated by the probabilistic operation scheme where the system could not return to its initial storage condition. The stochastic operation also showed 22 months of refilling (91.3% reliability). In the second scenario, the interconnection between Kolong Dam 1 Pemali and Kolong Simpur Pemali significantly improved system reliability. Simulation results indicated that the development demand could be consistently met across all seasons, with the stochastic operation showing only 7 months of refilling (97.2% reliability). Although it does not offer 100% reliability, the utilization of kolong already demonstrated improvements in water availability in Bangka Regency, Sumatra, helping to reduce the burden of meeting water needs in underdeveloped areas. The interconnection strategy between the pits is recommended as an effective technical solution to enhance the reliability of water supply for development needs in the study area.

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8. REFERENCES

[1] Schnepper T., Kühn M., Kempka T., Reaction Path Modeling of Water Pollution Implications of Pumped Hydropower Storage in Closed Open-pit Lignite Mines. Mine Water Environ, 44(1), 2025, pp. 1–15.

[2] Kunytska M., Digital Simulation Of Open-Pit Mining Organisation System. International Journal of GEOMATE, 25(109), 2023, pp. 197-204.

[3] Bourgeois J., Warren S., Armstrong J., Utilization of Statistical Analysis to Identify Influential Slope Parameters Associated with Rockfall at Open Pit Mines. Min Metall Explor, 40(1), 2023, pp. 1-12.

[4] Sakellari C., Roumpos C., Louloudis G., Vasileiou E., A Review about the Sustainability of Pit Lakes as a Rehabilitation Factor after Mine Closure. Materials Proceedings, 5(1), 2021, pp. 79-80.

[5] Burnama N.S., Rohmat F.I.W., Farid M., Wijayasari W., Utilization of quantile mapping method using cumulative distribution function (CDF) to calibrated satellite rainfall GSMaP in Majalaya watershed. IOP Conf Ser Earth Environ Sci, Vol. 1165 (1), 2023, pp.012006.

[6] Kuntoro A.A., Hapsari R.K., Adityawan M.B., Farid M., Widyaningtias, Radhia., Estimation of Extreme Rainfall over Kalimantan Island based on GPM IMERG Daily Data. IOP Conf Ser Earth Environ Sci, Vol. 1065 (1), 2022, pp. 1–8.

[7] Assidik M.L., Soekarno I., Widyaningtias, Humam I.A., Water balance analysis and hydraulic structure design to prevent peatland fires. IOP Conf Ser Earth Environ Sci, Vol.758 (1), 2021, pp.1–7.

[8] Yong S., Ng J.L., Huang Y., Ang C., Estimation of Reference Crop Evapotranspiration with Three Different Machine Learning Models and Limited Meteorological Variables. Agronomy, 13(4), 2023, pp. 1-15.

[9] Sun X., Zhang B., Dai M., Gao R., Jing C., Ma K., Gu S., Gu L., Zhen W., Gu X., Research on methods for estimating reference crop evapotranspiration under incomplete meteorological indicators. Front Plant Sci, 15(1), 2024, pp. 1-17.

[10] Hinwood J., McLean E., McMahon T., Water Balance and Evaporation for Two Intermittent Estuarine Lakes. Estuaries and Coasts, 48(4), 2025, pp. 1-15.

[11] Alfred B., Sayouba K., Fabien Y.H,. Xavier C., Ky T.S.M., Belkacem Z., Evaluation of Water Losses by Evaporation in the Nakanbe Basin. Atmos. Clim. Sci. Vol.14 (1), 2023, pp. 29–41.

[12] Wardhani E., Irmansyah A.Z., Fitriani N.A., Determining The Status Of The Setiamanah Reservoir Ecosystem In Cimahi City Of West Java Province. International Journal Of GEOMATE, 25(108), 2023, pp. 38-49.

[13] Soekarno I., Nugroho E.O., Nusantara Y.S., Study Of Water Supply And Water Demand For Estuary Reservoir Storage In Jakarta Bay (Case Study Of Cengkareng Drain River). 7th HATHI Seminar, Vol. 4 (1), 2021, p. 195–206.

[14] Kardhana H., Tatesawa H., Mano A., Flood forecast based on numerical weather prediction and distributed runoff model. WIT Transactions on Ecology and the Environment, Vol. 104 (1), 2007, pp. 201–211.

[15] Masduqi A., Nugroho A,, Wilujeng S., Solution To Water Scarcity In The Eastern Indonesia: A Case Study Of The Lembata Regency. International Journal of GEOMATE, 19(71), 2020, pp. 69–76.

[16] Sujana F.R., Chaidar A.N., Hatmoko W., Study on the Impact of Land Use Changes Caused by IKN Development on Sanggai River Flood Discharge. E3S Web of Conferences, vol. 500 (1), 2024, pp. 1 – 8.

[17] Suryadi Y., Chrysanti A., Nurnadiati F., Adityawan M.B., Kuntoro A.A., Study on Water Resources Allocation for Kertajati, Jatitujuh, and Ligung Sub-Districts to Support the Development of West Java International Airport (BIJB) and Kertajati Aerocity Area. MATEC Web Conf., Vol. 147 (1), 2018, pp. 1 – 6.

[18] Sukma B., Kristanto G., Dahlan A., Landfill design based on methane gas emission estimates at Jatibarang Final Disposal Site (TPA) in Semarang City using LandGEM 3.03 and its potential utilization as an energy source. Indonesian Journal of Multidisciplinary Science,

Vol.4 (1), 2025, pp.310–328.
[19] Burako M., Projection of Clean Water Demand in 2021 in Pulang Pisau City Using the Arithmetic Method. Scientific Journal of Civil Engineering, Vol.6 (1), 2018, pp.79–84.
[20] Dendukuri S., Asadi S., Raju M.V., Estimation of water quality index by weighted arithmetic water quality index method: A model study. International Journal of Civil Engineering and Technology, Vol.8 (4), 2017, pp.1215–1222.
[21] Anggreini D., Sukiyanto S., Saputra B.D., Population Projection With The Application of The Differential Equation of The Logistic and Exponential Model (Case Study: Yogyakarta Special Region Province). Mathline : Journal of Math. and Math. Edu., Vol.8 (3), 2023, pp.795–804.
[22] Aliyyah I., Hafiyusholeh M., Hamid A., Prasetijo D., Analysis of Clean Water Demand Projection at PDAM Tirta Dharma, Pasuruan City Using the Population Forecasting Method. Statistika, Vol.24 (1), 2024, pp.11–9.
[23] Sada K., Mashud M., Hadis M.S., Prawati B.E., Perbandingan Metode Semi Average dan Metode Least Squared In the Prediction of Airline Ticket Sales. Journal Media TIK, Vol.4 (1), 2021, pp.1–12.
[24] Cohen A., Migliorati G., Optimal weighted least-squares methods. The SMAI Journal of Comp. Mathematics, Vol.3, 2017, pp.181–203.
[25] ReVelle C., Optimizing Reservoir Resources: Including a New Model for Reservoir Reliability. Wiley, Vol.1 (1), 1999, pp.97-174.
[26] Utami P.D.K., Suharsono A.W.H., Harlan D., Farid M., Rohmat F.I.W., Nugroho E.O., Mardiyono A., The Application Of Stochastic Model In Cascade Reservoir Of Saguling, Cirata, And Jatiluhur Dam For Reservoir Standard Operation Procedure. ICSBE, Vol.1 (1), 2022, pp. 205–220.
[27] Nurkhaerani F., Nugroho E.O., Utami D.K., Suryadi C., Sugiarto A.R., Mardiyono A., Rachmadyanto H., Rapid Assessment of Effectiveness Pump Storage Power Plant of Jatiluhur Reservoir. E3S Web of Conferences EDP Sciences, Vol. 576 (1), 2024, pp. 1–15.
[28] Marselina M., Sabar A., Mushfiroh A., The Optimization Of Operational Patterns For The Cipanunjang-Cileunca Cascade Reservoir Using Continuous Models. International Journal of GEOMATE, Vol. 23 (1), 2022, pp. 27–36.
[29] Nurkhaerani F., Nugroho E. O., Soeharsono A. W. H., Harlan D., Winarsih N., Evaluation and Simulation of the Operation Pattern of the Ir. H. Djuanda Reservoir, Springer ICACE, Vol. 1 (1), 2023, pp. 455–472.
[30] Avila L., Mine M., Kaviski E., Probabilistic long-term reservoir operation employing copulas and implicit stochastic optimization. Stochastic Environmental Research and Risk Assessment, Vol. 34 (1), 2020, pp. 931–947.
[31] Soekarno I., Nugroho E.O., Farid M., Abi F., Oriandra R.D., Nugroho J., Pratna R., Pratama R.C., Rasyid F.A., The Effect Of Sand Trap On Sedimentation Distribution Of Cirata Dam To Maintain The Reservoir Age Of Use. Journal of GEOMATE, Vol. 27 (124), 2024, pp. 57–67.
[32] Gunawan S.P.W., Machimura T., Matsui T., Hendrayana H., Water Budget Assessment Under Rapid Urbanization In Yogyakarta, Indonesia Using A Distributed Water Balance Model. International Journal of GEOMATE, 25(111), 2023, pp. 24-32