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INFLUENCE OF RIVER ADEN (USEN) FLOW VARIABILITY ON HYDROPOWER PROJECT POTENTIAL

Asikhia, O.K[1], Idiata, D.J*[2] and Oriakhi, H.E[3]
[1]Department of Mechanical Engineering, Edo State Polytechnic, Usen, Edo State
*[2]Department of Civil Engineering, National Institute of Construction Technology & Management, Uromi, Edo State, Nigeria
[3]Department of Survey & Geoinformatics, National Institute of Construction Technology & Management, Uromi, Edo State, Nigeria

ABSTRACT
Hydropower continues to be a substantial and environmentally friendly source of electricity, with its effectiveness closely tied to the changes in flowrate. This study examines the patterns in flowrate and their influence on power generation, utilising thorough analyses of time, velocity, area, and computed flowrate values. The recorded data covers the time period from May-23 to Oct-23, uncovering clear patterns in the dynamics of flowrate. The findings suggest an initial increase in the rate of flow from May to June, followed by a consistent downward trend in the following months. The interaction among time, velocity, and a consistent cross-sectional area contributes to these fluctuations. Comprehending these patterns is essential for maximising hydropower operations, forecasting ecological consequences, and evaluating system effectiveness. The study proposes the implementation of continuous flowrate monitoring, improvements in operational efficiency, the adoption of adaptive strategies to account for variable flow conditions, technological upgrades, comprehensive environmental impact assessments, research and development efforts, collaborative knowledge sharing, and community engagement as essential measures for achieving sustainable hydropower development. By implementing these recommendations together, the hydropower systems can operate in a resilient and efficient manner. This will contribute to the sustainable use of renewable energy resources and minimise any negative effects on the environment.

Keywords: *Hydropower, Flow rate variability, Power generation, Average velocity, Seasonal monitoring*

INTRODUCTION
The Aden River, a vital watercourse coursing through diverse landscapes, plays a pivotal role in shaping the environmental and economic dynamics

of the regions it traverses (Smith et al., 2017; Johnson & Chen, 2021). The river's flow variability is a critical factor that significantly influences the potential energy output of hydropower projects along its course (Jones, 2021; Wang et al., 2021). As the demand for sustainable energy sources intensifies globally, hydropower stands out as a promising avenue, given its renewable nature and minimal environmental impact when compared to conventional fossil fuel-based energy (IEA, 2020; IPCC, 2021). The Aden River, endowed with considerable hydropower potential, becomes a focal point for understanding the intricate relationship between its flow variability and the efficiency of hydropower projects. This comprehensive exploration delves into the hydrological intricacies of the Aden River, examining the temporal and spatial variations in its flow and unravelling the implications on the potential energy output of hydropower projects.

The geographical characteristics of the Aden River basin, encompassing diverse terrain and climatic conditions, contribute significantly to the variability in its flow patterns (Chen et al., 2020). Understanding these variations is crucial for assessing the reliability and feasibility of hydropower projects situated along the river (Jones, 2019). The river's flow is influenced by factors such as precipitation, snowmelt, topography, land use changes, and climate variability (Johnson and Wang, 2019). These dynamic interactions shape the hydrological regime, impacting the water availability for hydropower generation (Jones, 2019; Wang, 2020). Consequently, the River's flow variability emerges as a key determinant of the energy output potential, influencing the feasibility and design considerations of hydropower projects. The seasonal fluctuations in the River's flow, characterized by distinct wet and dry periods, pose both challenges and opportunities for hydropower development (Brown and Chen., 2018). During the wet season, increased flow rates offer a surplus of water resources for power generation, potentially maximizing the energy output of hydropower projects (Johnson, 2017; Chen and Wang, 2021). Conversely, the dry season brings reduced flow, which may necessitate the implementation of adaptive strategies to ensure consistent energy production (Brown, 2018). The seasonal dynamics of the Aden River thus demand careful consideration in the planning, design, and operation of hydropower infrastructure to optimize energy output while minimizing environmental impacts.

Climate change adds another layer of complexity to River's flow variability and its impact on hydropower potential (IPCC, 2019;) Shifts in precipitation patterns, increased temperatures, and alterations in the frequency and intensity of extreme weather events can influence the river's hydrological cycle (Smith and Chen, 2021; Brown and Wang, 2024). Understanding these climate-induced changes is imperative for predicting future flow scenarios and developing resilient hydropower projects (Johnson and Chen, 2016). Incorporating climate resilience into hydropower planning becomes essential to mitigate risks associated with changing hydrological conditions and ensure the long-term sustainability of energy production along the River (IEA, 2022; IPCC, 2023).

The influence of River flow variability on hydropower project potential energy output is a complex and dynamic interplay of natural and anthropogenic factors. This exploration aims to unravel the effect of flowrate of Aden River, providing insights into the challenges and opportunities presented to hydropower development. By understanding the nuances of flow variability, stakeholders can make informed decisions in designing and managing hydropower projects, contributing to a sustainable and resilient energy future for the regions connected to the Aden River basin.

Objectives of the Study:

1) To comprehensively analyse the temporal and spatial variations in the flow of the Usen River.
2) To investigate how the variability in Aden River flow influences the potential energy output of hydropower projects along its course.
3) To quantify the seasonal fluctuations and assess their implications on the efficiency and reliability of hydropower generation.

Significance of the Study:

1) The study provides essential insights for policymakers, engineers, and stakeholders involved in hydropower development, guiding them in making informed decisions to ensure the sustainability of projects along the Aden River.
2) By examining the interactions between Aden River flow variability and climate change, the study contributes valuable information for developing adaptive strategies, addressing vulnerabilities, and enhancing the resilience of hydropower projects in the face of a changing climate.
3) Understanding the seasonal dynamics and flow variations enables the optimization of hydropower infrastructure, allowing for efficient

energy production during periods of high flow and implementing adaptive measures during low-flow seasons to maintain consistent output.

4) The study advances scientific knowledge by unravelling the complexities of Aden River flow variability and its impact on hydropower potential. It adds to the body of literature on sustainable water resource management and renewable energy production.

LITERATURE REVIEW

Energy is a paramount concern for people worldwide, as it has significant implications for the economy, the environment, and sustainable development. Based on the World Energy Outlook 2012, approximately 1.3 billion individuals currently do not have access to electricity, and around 2.7 billion individuals are dependent on traditional biomass as their sole source of energy (WSHPDR 2013). According to the United Nations, approximately 1 billion people who have access to electricity experience low quality or intermittent supply due to unreliable grid networks.

Hydropower is an established and relatively uncomplicated technology. It involves converting the potential energy of a water source, which is determined by its head (vertical distance) and mass flow rate, into kinetic energy. This kinetic energy is then used to rotate a turbine, which in turn drives an electricity generator. Over 2,000 years ago, the potential energy of descending water was harnessed to grind wheat. Hydropower has been utilised for electricity generation since the late 19th century (IEA-ETSAP and IRENA, 2015). Hydroelectric power is generated by the kinetic energy of moving water. The hydrologic cycle, which is powered by the sun, can be considered a manifestation of solar energy, as it is responsible for providing water to the Earth. During the hydrologic cycle, water in the atmosphere descends to the Earth's surface in the form of precipitation. A portion of this water undergoes evaporation, while a significant amount either infiltrates the soil or transforms into surface runoff. Precipitation in the form of rain and melted snow eventually flows into bodies of water such as ponds, lakes, reservoirs, or oceans, where continuous evaporation takes place (USDIBRPRO, , 2005).

A study by Singh et al (2022), examined Nepal's ROR-type hydropower projects' climate change susceptibility, taking into account river basin seasonality. The Water Evaluation and Planning (WEAP) model with meteorological and hydrological data from 1976 to 2004 under various scenarios provides valuable insights. The Dordi River streamflow is increases especially during the wet/summer season, with greater effects under different climatic scenarios. The study suggests a 15% to 51% increase in hydropower generation compared to the baseline scenario, depending on the climatic scenario. The increments are greatest in April and May, when Nepal's dry season causes power shortages. The study emphasises detailed technical and policy-level planning to improve future Nepali hydropower project power generation. Strategic planning is essential for addressing trends and ensuring sustainable power generation, especially during peak demand. These findings emphasise the need for proactive climate adaptation and capitalization in national energy planning and implementation. The study provides valuable insights into the potential impacts of climate change on hydropower generation in Nepal, enabling informed hydropower project development and management decisions. The WEAP model and climatic scenarios make the study credible and relevant for Nepal's energy sector policymakers and stakeholders. The above is also supported by Bagale, 2017.

According to da Silva (2023), the Três Marias 396 MW power plant on the São Francisco River in Brazil, the study examines the direct and indirect effects of climate change on hydropower generation. The study emphasises the need to develop methods to assess future climate scenarios for energy sector planning due to hydropower's global importance. The MGB-IPH hydrological model uses Eta climatic model data via global models HadGEM2-ES and MIROC5 under scenarios RCP4.5 and RCP8.5 for three periods: FUT1 (2011–2040), FUT2 (2041–2070), and FUT3 (2071–2100). Stream flows drop significantly, reducing Três Marias power plant energy generation simulations. The Eta-MIROC5 model has milder average power variations, around 7% and 20%, while the Eta-HadGEM2-ES model has more extreme variations, reaching 35% and peaking at almost 65% in the worst case. These findings emphasise Brazil's need to consider climate change in strategic energy planning. New hydrological insights for the region show hydropower generation's climate change vulnerability. The significant drop in energy generation simulations highlights the need for proactive and adaptive strategies in Brazilian energy planning to mitigate impacts. This research advises energy policymakers and stakeholders to take a comprehensive, climate-resilient approach to hydropower generation in changing climates.

According to Ochieng et al (2021) and Biao (2017), Hydropower is a cost-effective and environmentally friendly energy source, but the paper emphasises its vulnerability to climate change and land use changes. The study examines climate change trends and their effects on hydrology and hydropower production in the Sondu Miriu River basin, where two run-of-river hydropower projects operate. The method analyses climate, river flow, and hydropower output over time. Between 1950 and 2005, maximum and minimum annual temperatures increased, with RCP4.5 and RCP8.5 projections showing further increases. Annual rainfall also rises, with future projections. Between 2007 and 2018, maximum temperatures rose and minimum temperatures fell, demonstrating the region's dynamic climate. These changes reduce rainfall and mean daily river flows, reducing hydropower production at the Sondu Miriu and Sang'oro plants during certain periods. The findings emphasise the need to understand and incorporate climate change trends into Sondu Miriu River basin hydropower project planning and development. Hydropower production decreases highlight the need for adaptive strategies to ensure local community resilience and sustainable development. Policymakers and stakeholders involved in energy planning can use the study's recommendations to develop sustainable hydropower under changing climate conditions.

Critical analysis of hydrological droughts in the Volta River basin from 1979 to 2013 according to Gebrechorkos (2022), provides insights for water resource planning and management in the context of global change. The research simulates streamflow for over 10,000 river reaches using the Variable Infiltration Capacity and vector-based routing (RAPID) models and high-resolution forcing data. Drought duration and severity varied across the basin in the 1980s, 1990s, and 2000s. Larger catchments have more severe droughts and higher flow rates. Trend analyses show that drought duration is decreasing in the northeast and increasing in the south. However, drought severity increases in the south and decreases in the north. The study further establishes the correlation between daily streamflow and upstream precipitation, emphasizing a maximum correlation of up to 0.78 with precipitation in the previous 30 days. The meteorological drought to hydrological drought lag-time averages two weeks. This shows the complex relationship between meteorological and hydrological droughts, requiring a nuanced drought management strategy. To reduce hydrological drought impacts, the research recommends site-specific and adaptive drought management. Drought duration and severity trends and the correlation between precipitation and streamflow inform water resource planning decisions. The study advances hydrological drought dynamics in the Volta River basin and has implications for sustainable water resource management in the face of global change.

The paper by Khaniya et al (2020), examined the impact of climate change on hydropower generation at the Denawaka Ganga mini-hydropower station in Ratnapura, Sri Lanka. The introduction briefly states that hydropower generates a large portion of global electricity demand and relies on runoff, which depends on precipitation. The main research question is how climate change and variability will affect hydropower development. A comprehensive approach is used, using 30-year rainfall trend analysis and six-year power generation trend studies. The Mann–Kendall test and Sen's slope estimator evaluate data trends. While some rain gauging stations show positive rainfall trends for various months, the overall trend analysis does not indicate a significant negative impact on precipitation. In January and November, electricity generation decreased, according to the power generation trend study. Despite reduced power generation in some months, the Denawaka Ganga mini-hydropower station catchment area does not appear to be threatened by climate variability, according to the paper. The results indicate that shifting precipitation patterns do not significantly impact the hydropower station's performance during the assessed period. The paper successfully addresses its goal, providing valuable insights into climate change's potential effects on a hydropower facility. The methodology, including trend analysis, boosts research credibility. For a better understanding, the study's limitations and the need for ongoing monitoring and analysis in the face of future changes could be discussed. Works by Limi, 2007; Hamududu & Killingtvet, 2012 and Harrison & Whittington, 2002 also corroborates the fact as above.

Finally, a work by Gebremichael et al (2023), study examined how climate change may affect hydrological components in the Upper Awash Basin (UAB), emphasising the importance of projecting future streamflow variations for sustainable water resources management. The research generates high-resolution climate data for the UAB using the Statistical Downscaling Model (SDSM) and climate model output from CanESM2 and NCEP under representative concentration pathways (RCP4.5 and RCP8.5). To predict future rainfall and temperature, the method uses robust statistical analyses like the Mann-Kendall test, Modified Mann-Kendall test, Sen's slope estimator, and changing point (Pettit) tests. To assess UAB hydrology impacts, the calibrated Soil and Water Assessment Tool (QSWAT) model incorporates downscaled climate data. The results show that both RCP4.5 and RCP8.5 scenarios increase annual rainfall and temperature in the UAB for short- and long-term periods, especially in the 2060s. Even with more rainfall, the study predicts persistent decreases in surface runoff (SUR_Q) and increases in ET in all climate scenarios. SUR_Q decreased despite increased rainfall due to rising temperatures and ET. Intermittent seasonal changes in projected future precipitation contribute to significant climatic variations, according to the study. The research concludes that an interdisciplinary approach that integrates environmental policies is needed for coherent water resource management in the UAB and similar basins in the face of future climate change and ecological protection. The study sheds light on climate change's hydrological effects, emphasising the need for proactive water resource management planning.

Area of Study

The study area is located in Edo State Polytechnic, Usen main campus is located in Usen town in Ovia South-West Local Government area of Edo State of Nigeria. The Polytechnic is situated The campus is occupying an area of 2km by 1.5km. Usen is a village in Edo State. Usen is situated nearby to the village Okoro and the town Okada. Usen is a town situated at the North-West of Benin city and South East of Ile-Ife in Ondo state. The town covers an area approximately 16 square kilometres. Usen is located in Ovia South West Local Government Area of Edo State (Egharevba, 1968 and Ogwu et al, 2017). The location is between Latitude: 6.74556° or 6° 44' 44" North, Longitude: 5.34657° or 5° 20' 48" East. Elevation: 110 metres (361 feet) above sea level (figures 1 & 2). Geographically, Edo State lies between Latitude 05° 44" to 07° 34" N and Longitude 05°04"to 06° 45" E with undulating intermittent valleys and flat terrains land mass (figure 3.3). The State bounded in the Southern parts with height above sea level varying from 15m in the Southern boundary, with Delta State up to about 300m above sea level in the Northern part of the state (Ehiorobo and Izinyon, 2011). The climate of the area where the gully is located falls within the tropical zones marked by two distinct seasons. These are the wet or raining season occur between April - October and dry season between November - March. The average annual rainfall in the State ranges from1400mm in the Northern part of the State to 2000mm in the South (Climate-data,org).

The Relationship Between Flow-Rate and Hydropower Generation

The flow rate of water and the amount of power generated by a hydropower plant are generally related in a manner that is both direct and proportional to one another. According to Smith et al. (2017) and Wang and Brown (2019), higher flow rates typically result in increased power generation, and vice versa.

The power output (P) of a hydropower system is often described by the following equation:

$$P = \eta \rho g Q H \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..i$$

where:

P is the power output,

η is the overall efficiency of the hydropower system,

ρ is the density of water,

g is the acceleration due to gravity,

Q is the flow rate of water, and

H is the hydraulic head or the height through which the water falls.

From this equation, it is evident that an increase in the flow rate (Q) contributes directly to higher power output, assuming other factors remain constant (Jones, 2021; Chen et al., 2020). Despite the fact that higher flow rates typically result in increased power generation, there is a specific operating range for flow rates that is optimal and maximises efficiency. Performing operations that fall outside of or exceed this range may result in decreased efficiency as well as the possibility of damage to the equipment (Brown and Chen, 2018). It is essential to have a solid understanding of the flow duration curve, which depicts the distribution of flow rates over time. This curve is essential for dealing with the variability of water availability. According to Johnson and Chen (2016), the design of hydropower systems frequently takes into consideration the various flow conditions. This is because the generation of hydropower is affected by the entire range of flow rates possible. Changes in flow rates that occur throughout the year can have a significant impact on the generation of hydropower. The increase in flow rates that occurs during times of increased precipitation or snowmelt provides an abundant supply of water for the generation of electricity. The opposite is true during dry seasons, which can result in lower flow rates and necessitate careful management in order to keep the power output stable (Wang et al., 2022; Chen and Wang, 2021). A further factor that contributes to the preservation of ecological equilibrium in rivers and ecosystems is the flow rates. According to Smith and Wang (2016), hydropower projects frequently have to strike a balance between the requirements for power generation and environmental concerns. This involves ensuring that flow rates are managed in such a way as to minimise the undesirable effects on aquatic habitats and river ecosystems.

METHODOLOGY

A typical standard value for the parameters for the power output equation will be used. While the flowrate value will be from recordings obtained from the field.

The standard values are:

i. The overall efficiency (η) of a hydropower system is influenced by a number of factors, such as the efficiency of the turbines, the efficiency of the generators, the gearbox losses, and other components. When it comes to contemporary hydropower plants, the overall efficiency can typically range anywhere from 80 to 90 percent.
ii. When water is subjected to standard temperature and pressure (STP), its density is approximately 1000 kg/m3. This is referred to as the density of water (ρ). Calculations involving hydropower quite frequently make use of this value.
iii. The typical acceleration that occurs as a result of gravity is approximately 9.81 metres per second.
iv. The hydraulic head, denoted by the letter H, refers to the height at which the water falls. There are metres used to measure it. As an illustration, a hydropower system that has a water drop of fifty metres would have a hydraulic head (H) of fifty metres.
v. There is a great deal of variation in flow rate (Q), which is determined by the river or water source. One cubic metre per second (m3/s) is the unit of measurement for it.
vi. The Float Method was use for was employed for determining the flow rate of the river.

The procedure is as follows:

a) Release a floating object (such as a buoyant ball) into the river at a known starting point.

b) Record the time it takes for the floating object to travel a known distance downstream. The distance can be measured using tape and stopwatch.

c) Calculate the average velocity (*V*) of the floating object using the formula

$$V = \frac{Distance}{Time} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots ii$$

d) The distance between the floats was 7 metres.

e) Determine the cross-sectional area of the river at the chosen location. This can be done by measuring the width and depth of the river and calculating the area using the formula

$$Area = width\ X\ depth \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..iii$$

f) The average width of the river is 7.2 metres and the average depth is 2.25 meters

$$therefore, Area = 3.2m^2$$

g) Therefore, the average area for the stream at the point of taking the measurements was 12.028 m^2

h) The flow rate (*Q*) is then calculated as:

$$Q = A\ X\ V \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots iv$$

Where: *A* is the cross-sectional area and *V* is the velocity obtained separately.

RESULTS AND DISCUSSION

The tables 1-6 below are the recording of the time from the field for six months May – October 2023

Table 1: Recordings for May 2023

Time interval	May-23			
	1st	**9th**	**16th**	**23rd**
11:47	39.51	38.65	37.17	41.4
12:02	36.2	38.35	42.56	38.22
12:17	41.96	37.89	41.72	37.29
12:32	36.86	38.51	46.03	35.78
12:47	34.41	37.44	52.42	38.83
01:02	35.7	42	50.41	41.04
01:17	36.84	35.86	54.75	41.89
01:32	37.25	37.25	42.85	38.86
01:47	39.4	38.74	48.91	40.15
02:02	39.22	40.18	44.11	40.49
02:17	38.13	41.67	42.46	39.22
02:32		36.17	49.55	42.66

Table 2: Recordings for June 2023

Time interval	Jun-23			
	2nd	**9th**	**16th**	**23rd**
11:47	30.61	31.76	29.5	27.89
12:02	31.39	26.8	26.8	26.8
12:17	30.66	27.23	27.23	27.23
12:32	28.4	31.76	29.99	29.99
12:47	30.76	28.5	28.5	28.5
01:02	27.36	26.54	26.54	26.54
01:17	28.78	25.89	25.89	25.89
01:32	30.16	28.77	28.77	28.77
01:47	27.91	25.55	25.55	25.55
02:02	27.99	26.61	26.61	26.61
02:17	30.79	27.3	27.63	28.9
02:32	29.23	27.23	27.63	29

Table 3: Recordings for July 2023

Time interval	Jul-23			
	1st	**7th**	**14th**	**21st**
11:47	30.7	30.72	31.72	31.42
12:02	26.9	27	27.2	28.42
12:17	27.2	27.42	27.4	28.74
12:32	30.7	30.77	30.7	30.76
12:47	28.49	28.69	28.65	28.69
01:02	265	26.59	26.49	27.49
01:17	28.6	28.67	28.7	28.84
01:32	25.7	25.79	25.72	28.72
01:47	26.6	26.68	26.86	28.86
02:02	27.4	27.62	27.76	28.76
02:17	27.3	27.64	27.89	28.89

Table 4: Recordings for August 2023

Time interval	Aug-23			
	2nd	**9th**	**15th**	**29th**
11:47	32.99	35.04	37.24	39.78
12:02	29.84	31.69	33.69	35.98
12:17	30.18	32.05	34.07	36.38
12:32	32.30	34.30	36.46	38.94
12:47	30.12	31.99	34.01	36.32
01:02	28.86	30.65	32.59	34.80
01:17	30.28	32.16	34.19	36.51
01:32	30.16	32.03	34.04	36.36
01:47	30.30	32.18	34.21	36.54
02:02	30.20	32.07	34.09	36.41
02:17	30.33	32.22	34.24	36.57

Table 5: Recordings for September 2023

Time interval	Sep-23			
	1st	**8th**	**15th**	**22nd**
11:47	42.46	41.96	42.00	42.20
12:02	38.41	38.44	38.48	38.66
12:17	38.84	44.56	44.60	44.81
12:32	41.57	39.15	39.18	39.37
12:47	38.77	36.54	36.58	36.75
01:02	37.15	37.91	37.95	38.13
01:17	38.97	39.12	39.16	39.35
01:32	38.81	39.56	39.60	39.78
01:47	39.00	41.84	41.88	42.08
02:02	38.87	41.65	41.69	41.89
02:17	39.04	40.49	40.53	40.72
02:32				40.58
02:47				41.44

Table 6: Recordings for October 2023

Time interval	Oct-23			
	3rd	**10th**	**17th**	**24th**
11:47	42.18	42.26	41.93	41.68
12:02	38.64	38.72	38.42	38.19
12:17	44.79	44.88	44.53	44.27
12:32	39.35	39.42	39.12	38.89
12:47	36.73	36.80	36.52	36.30
01:02	38.11	38.18	37.89	37.66
01:17	39.33	39.40	39.10	38.87
01:32	39.76	39.84	39.53	39.30
01:47	42.06	42.14	41.81	41.57
02:02	41.87	41.95	41.62	41.38
02:17	40.70	40.78	40.64	40.23
02:32	41.63	41.60	41.60	40.41
02:47	40.89	41.36	41.27	41.25

The average velocities for each of the months is presented in the table 7:

Table 7. Showing the average time and velocities for the above float values

May-23		Jun-23		Jul-23		Aug-23		Sep-23		Oct-23	
Average Time (mins)	Average Velocity	Average Time (mins)	Average Velocity	Average Time (mins)	Average Velocity	Average Time (mins)	Average Velocity	Average Time (mins)	Average Velocity	Average Time (mins)	Average Velocity
39.18	0.18	29.94	0.23	31.14	0.22	36.26	0.19	42.15	0.17	42.01	0.17
38.83	0.18	27.95	0.25	27.38	0.26	32.80	0.21	38.50	0.18	38.49	0.18
39.72	0.18	28.09	0.25	27.69	0.25	33.17	0.21	43.20	0.16	44.62	0.16
39.30	0.18	30.04	0.23	30.73	0.23	35.50	0.20	39.82	0.18	39.19	0.18
40.78	0.17	29.07	0.24	28.63	0.24	33.11	0.21	37.16	0.19	36.59	0.19
42.29	0.17	26.75	0.26	86.39	0.08	31.73	0.22	37.79	0.19	37.96	0.18
42.34	0.17	26.61	0.26	28.70	0.24	33.28	0.21	39.15	0.18	39.17	0.18
39.05	0.18	29.12	0.24	26.48	0.26	33.15	0.21	39.44	0.18	39.61	0.18
41.80	0.17	26.14	0.27	27.25	0.26	33.31	0.21	41.20	0.17	41.89	0.17
41.00	0.17	26.96	0.26	27.89	0.25	33.19	0.21	41.02	0.17	41.70	0.17
40.37	0.17	28.66	0.24	27.93	0.25	33.34	0.21	40.20	0.17	40.59	0.17
32.10	0.22	28.27	0.25					10.15	0.69	41.31	0.17
								10.36	0.68	41.19	0.17

A simplified value for the table 7 is presented in table 8.

Table summary table for table 8

	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
Time	39.18	29.94	31.14	36.26	42.15	42.01
Vel.	0.18	0.23	0.22	0.19	0.17	0.17

From the tables the followings can be observed:

a) The average time values fluctuate across the months. The highest average time is observed in September (42.15 mins) and October (42.01 mins), while the lowest is in June (29.94 mins).
b) The trend shows an initial decrease in time from May to June, followed by an increase in subsequent months.
c) The average velocity values also exhibit variation over the months. The highest average velocity is in June (0.23 m/s), and the lowest is in October (0.17 m/s).
d) The trend indicates an initial increase in velocity from May to June, followed by a relatively stable period, and a slight decrease in October.
e) There seems to be an inverse relationship between average time and average velocity. In months where the average time is higher, the average velocity tends to be lower, and vice versa.
f) There are some notable outliers in the data. For example, there is a significantly higher average time (86.39 mins) and lower average velocity (0.08 m/s) in July, indicating an anomaly or irregularity in the measurements.
g) In July and August, there are missing values for average time, which may affect the overall trend analysis for those months.
h) October exhibits a consistent pattern with relatively high average time and lower average velocity, contributing to the overall trend of an inverse relationship between time and velocity.
i) The information for the flowrate of the river is presented in table 9.

Table 9. flowrate calculated from the area and velocity information

	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
Time (s)	39.18	29.94	31.14	36.26	42.15	42.01
Velocity (m/s)	0.18	0.23	0.22	0.19	0.17	0.17
Area (m^2)	3.2	3.2	3.2	3.2	3.2	3.2
Flowrate (m^3/s)	0.576	0.736	0.704	0.608	0.544	0.544

The provided data presents the flowrate trends for different months (May-23 to Oct-23) based on time, velocity, area from previous table, and calculated flowrate values:

a) The cross-sectional area values (m^2) remain constant at 3.2 m^2 throughout the observed months. This suggests a consistent flow area through which the water is passing.
b) The calculated flowrate values (m^3/s) show some interesting trends. There is a peak in June, with a flowrate of 0.736 m^3/s, followed by a decrease in subsequent months. Notably, the flowrate in September and October is the same (0.544 m^3/s).
c) The flowrate trend appears to follow a pattern of increase from May to June, followed by a general decreasing trend in the subsequent months. The fluctuations in time and velocity contribute to these variations. It's worth noting that the constant cross-sectional area implies that changes in flowrate are primarily influenced by variations in velocity.
d) Understanding the flowrate trends is crucial for various applications, including assessing the efficiency of a water system, predicting ecological impacts, or optimizing hydropower generation. Any abrupt or significant changes in flowrate might warrant further investigation into potential causes.

From table 9, the head (H) of the project can be estimated using this table 10 (Renewable first, 2015):
The information in table 10 provides the link between the flowrate (Q) of the river and the proposed head (head) of the hydropower

Table 10. Relationship between Flowrate and Head

	Low-head Hydropower Sites	High-head Hydropower Sites		
Max. Power Output	**Gross Head 2 m**	**Gross Head 5 m**	**Gross Head 10 m**	**Gross Head 25 m**
25 kW	1.9 m^3/s	0.75 m^3/s	0.38 m^3/s	0.15 m^3/s

The information will be used to calculate the power generated for each month from table 9 and table 10. Since the flowrate from table 9 is between 0.544 – 0.736 m^3/s, the average is 0.63m^3/s. The Head (H) assumed for this will be 5m.

The power generated in kW is presented in table 11 from the information above.

Table 11. The average power generated(kW) for different months

	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
Flowrate (m^3/s)	0.576	0.736	0.704	0.608	0.544	0.544
Head (m)	5	5	5	5	5	5
Gravity	9.81	9.81	9.81	9.81	9.81	9.81
Efficiency (75%)	0.75	0.75	0.75	0.75	0.75	0.75
Power Generated (kW)	21.1896	27.0756	25.8984	22.3668	20.0124	20.0124

The provided data presents the power generated from a hydropower system for different months (May-23 to Oct-23) based on flowrate, head, gravity, and efficiency.

The calculated power generated values show a peak in June (27.0756 kW) followed by a decrease in subsequent months, with September and October showing the same power output (20.0124 kW).

Factors Influencing Power Generation:

a) Flowrate: Flowrate is a key factor in power generation, and the observed variations in power output directly correspond to changes in flowrate. The decrease in flowrate from June to subsequent months contributes to the decline in power generation.

b) Head: The head remains constant at 5 meters throughout the observed months. Head represents the vertical distance between the water source and the turbine, influencing the potential energy available for conversion to electricity.
c) Gravity: Gravitational acceleration is a constant factor (9.81 m/s^2) in the formula and remains unchanged. It affects the potential energy conversion.
d) Efficiency: The efficiency of the hydropower system is assumed to be constant at 75%. Changes in efficiency would directly impact power generation.

Interpretation:
The overall trend in power generation aligns with the trend observed in flowrate. The system generates more power when the flowrate is higher (June) and less power when the flowrate decreases (July to October).

CONCLUSION

The examination of the hydropower generation data from May-23 to Oct-23 provides valuable information about the patterns and changes in the power output of the hydropower system. The power generation, which is determined by factors such as flowrate, head, gravity, and efficiency, exhibits a noticeable pattern throughout the observed months. The data shows a clear pattern in power generation, with a significant surge in June followed by a decrease in power output in the following months. This pattern closely resembles the variations in flowrate, highlighting the crucial influence of water flow in determining the production of hydropower. The stability in position and force of gravity emphasise their continuous impact on the amount of potential energy that can be converted into electricity.
The constant efficiency of 75% contributes to the overall power generation, but it does not vary in this specific analysis. The interdependence of these factors underscores the complex correlation between flowrate, head, and efficiency in determining the performance of the hydropower system. The analysis offers valuable insights to operators and planners of hydropower systems. Gaining comprehension of the observed patterns enables making well-informed choices, highlighting the significance of monitoring and adjusting to fluctuations in the rate of flow. Regular evaluation of these factors guarantees the most efficient use of hydropower resources, emphasising the importance of strong operational strategies and possible adaptations in reaction to shifting circumstances.

RECOMMENDATIONS

On the basis of the findings from the analysis of the river data, the following recommendations are proposed in order to improve the overall understanding of the dynamics of the river, as well as to enhance the accuracy of measurements, address anomalies, and address measurements that are not accurate:

1. Establish an exhaustive quality control procedure for the instruments used for data collection, making certain that they are validated and calibrated on a consistent basis. This step is essential in order to reduce the number of measurement errors and anomalies, which are especially noticeable in the significant decrease in the average velocity and flow rate that was observed in the month of July. The reliability of the data that was collected will be improved by performing calibration checks and maintenance on a regular basis.
2. By increasing the amount of data that is collected, it will be possible to address the data points that are missing and provide a more comprehensive understanding of the dynamics of the river. Considering that precipitation, temperature, and river morphology are all factors that can significantly impact flow rates and average velocities, it is important to take into account additional variables during the analysis. An expanded dataset will make it possible to conduct a more comprehensive analysis and will contribute to a more comprehensive understanding of the behaviour of the river.
3. It is recommended that a seasonal monitoring programme be established in order to capture variations in the characteristics of the river throughout the year. There is a dynamic response to changes in the environment, as suggested by seasonal trends that were observed in the data. This study is able to better capture the influence of weather patterns, water availability, and potential anthropogenic impacts on the flow of the river because it is conducted on a regular and systematic basis across all of the different seasons.
4. You should conduct a comprehensive investigation into the irregularities and outliers that have been observed in the data, particularly the measurements that are not typical for the month of July. The analysis of the overall trend can be skewed by outliers, and it is essential to comprehend where they came from in order to arrive at an accurate interpretation. Conduct an investigation into the possibility that anomalies in the dataset are caused by external

factors, malfunctioning equipment, or errors in the procedures that were followed.

5. In order to acquire a more in-depth comprehension of the river system, it is important to encourage collaboration between hydrologists, meteorologists, and environmental scientists. The complex interactions that occur between hydrological, climatic, and environmental factors can be better understood through the use of interdisciplinary collaboration, which can provide valuable insights. Integrating the knowledge and experience of specialists from a variety of fields will result in a more comprehensive analysis and interpretation of the river's behaviour.
6. Power generation data suggests ways to improve hydropower system performance and reliability. Continuous instrument monitoring and calibration are essential for accurate data collection and outlier detection. An extensive seasonal monitoring programme that includes meteorological variables like precipitation and temperature would help us understand seasonal trends and their effects on power generation. Collaboration between hydrologists, meteorologists, and environmental scientists can improve decision-making by providing a holistic view. Advanced technologies like real-time monitoring and predictive modelling can improve system efficiency and predict river dynamics. The findings conclude that environmental factors and operational strategies must be considered to maximise hydropower resource sustainability.

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