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ASSESSMENT OF ENVIRONMENTAL IMPACTS AND ENVIRONMENTAL FLOW FOR RIVER TYPE HYDROELECTRIC POWER PLANT: THE CASE OF KORKUTELI STREAM (ANTALYA)

NEHİR TİPİ HİDROELEKTRİK SANTRALİ İÇİN ÇEVRESEL ETKİLERİN VE ÇEVRESEL AKIŞIN DEĞERLENDİRİLMESİ: KORKUTELİ ÇAYI ÖRNEĞİ (ANTALYA)

İ. İskender SOYASLAN[1*] (ORCID: 0000-0001-5282-8094)

[1] Burdur Mehmet Akif Ersoy University, Department of Civil Engineering, Burdur, Türkiye

*Sorumlu Yazar / Corresponding Author: İ. İskender SOYASLAN, isoyaslan@mehmetakif.edu.tr

ABSTRACT

Considering Türkiye's morphological structure and river beds, it can be seen that it has not yet reached its equilibrium profile. This profile is an ideal structure for installing hydroelectric power plants (HPP). After renewable energy sources, the most environmentally friendly energy source for the ecosystem is HPP. When determining the amount of water to be used in hydroelectric power plants, the amount of water required for the ecosystem that should be discharged to nature should be calculated. The amount of water needed for the ecosystem to maintain its current structure without change is defined as the environmental flow. In this study, the environmental impact and environmental flow of the Korkuteli Stream HPP Project located within the borders of the Korkuteli District of Antalya Province have been determined. Wetted perimeter, flow duration index (Q25, Q50, Q75, and Q95), and base flow methods have been used to determine the environmental flow of the Korkuteli Stream. In calculating environmental flow 44 years of discharges of the Salamur Strait flow observation station (FOS) on Korkuteli Stream have been used. As a result, the optimal environmental flow was calculated at 17% using the wetted perimeter method.

Keywords: Environmental flow, Korkuteli Stream, Environmental impact, Hydroelectric power plant

ÖZET

Türkiye'nin morfolojik yapısı ve akarsu yatakları göz önüne alındığında henüz denge profiline ulaşmadığı görülmektedir. Bu profil hidroelektrik santrallerin kurulumu için ideal bir yapıdır. Yenilenebilir enerji kaynaklarından sonra ekosistem için en çevre dostu enerji kaynağı hidroelektrik santralleridir (HES). Hidroelektrik santrallerde kullanılacak su miktarını belirlerken ekosistem için gerekli olan ve doğaya deşarj edilmesi gereken su miktarı hesaplanmalıdır. Ekosistemin mevcut yapısını değiştirmeden sürdürebilmesi için ihtiyaç duyduğu su miktarı çevresel akış olarak tanımlanmaktadır. Bu çalışmada, Antalya İli Korkuteli İlçesi sınırları içerisinde yer alan Korkuteli Çayı HES Projesi'nin çevresel etkisi ve çevresel akışı belirlenmiştir. Korkuteli Çayı'nın çevresel akışını belirlemek için ıslatılmış çevre, akış süresi indeksi (Q25, Q50, Q75 ve Q95) ve taban akış yöntemleri kullanılmıştır. Çevresel akışın hesaplanmasında Korkuteli Çayı üzerindeki Salamur Boğazı debi ölçerinin 44 yıllık deşarjları kullanılmıştır. Sonuç olarak ıslak çevre yöntemi ile optimum çevresel akış %17 olarak hesaplanmıştır.

Anahtar Kelimeler: Çevresel akış, Korkuteli Çayı, Çevresel etki, Hidroelektrik santral

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INTRODUCTION

Global energy demand is rising by 4-5% annually due to technological advancement, population growth, and rising standards of living (Kaygusuz, 2022; Kaya et al., 2018). Different energy sources are used to fulfill the increasing energy demand. The sources include chemical reactions from mineral resources, nuclear reactions, gravitational potential from the Earth's lunar and solar movements, chemical processes, and natural radioactive decay. Energy sources are divided into two categories: conventional and renewable. Renewable energy sources are classified as biomass, wind, solar, hydroelectric, geothermal, and tidal waves. Conventional energy sources are radioactive energy, natural gas, oil, and coal (Twidell & Weir, 2015). In recent years, the use of non-renewable energy sources to fulfill energy requirements has resulted in adverse effects. In this case, the trend toward renewable energy sources has increased worldwide (Altınkaya & Yılmaz, 2023). As a result, governments have increased their investments in renewable energy sources (Şalvarlı, 2023; Özbektaş et al., 2023; IHA, 2020). Renewable energy sources possess a sustainable cycle due to their direct production in natural environments and their continuous renewal. Because it doesn't require additional raw materials for processing and production, renewable energy is economical (Külekçi, 2009).

According to Dursun and Saltuk (2023), HPPs hold the largest share of renewable energy in the world. HPP transforms potential energy into mechanical energy by utilizing the elevation difference in the water. Mechanical energy is defined as engineering structures that transform it into electrical energy by moving turbines (Süme and Fırat, 2020; Atalay and Yılmaz Ulu, 2018; Yaşar, 2018). HPP, one of the major renewable energy sources, has a very important place in Türkiye compared to other electricity generation methods. The most important reason for this is the topographical and geological structure of Türkiye (Karadol, Avli Firiş and Şekkeli, 2023). The reason for this is the difference in elevation between the spring locations of the streams and the locations where they flow into the sea or lake. Since the rivers in Türkiye do not reach the equilibrium profile like those in Europe, this elevation difference provides favourable conditions for HPP (Cronin et al., 2000; Soyaslan, 2019; Karakoyun & Yumurtacı, 2015). Türkiye has great advantages in terms of HPP potential and the importance of hydroelectric energy, which is a clean and renewable energy source, is increasing day by day (Bobat, 2023; Soyaslan, 2019; Ateş, Doğan & Berktay, 2016). As a developing country, Türkiye's need and demand for energy is increasing day by day. With this increase, HPP investments in the country have increased significantly in the last decade. However, an investment approach that threatens natural life assumes nature as a commercial resource and develops uncontrollably is dominant in the country (Babacan & Yüksek, 2022).

Hydroelectric power plants are systems that transform water energy into mechanical energy by transporting water from a higher elevation to a lower elevation. Before the construction of the HPP plant, all species in the surrounding environment depended on water which was the basic requirement of the HPP. Throughout the design, building, and operational stages of a hydropower plant, it is essential to determine the water requirements for the survival of every organism inside the ecosystem. Determining the water requirements is a crucial aspect of this research and all HPPs.

The advantages of HPPs are low maintenance and operating costs, the ability to be installed with domestic resources, amortization period, long operating life, renewability, environmental friendliness, no waste as a result of the process, and no need for fuel (Albayrak & Turanlı, 2022; Karakoyun & Yumurtacı, 2015). According to worldwide electricity generation statistics, the amount of electricity generation, which was 11957 terawatt-hours in 1990, reached 29165 terawatt-hours in 2022 (Fig. 1) (Statista, 2023).

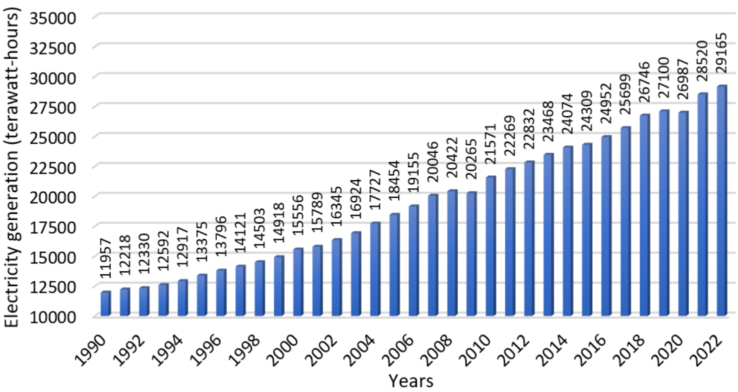

Figure 1. Electricity Generation Worldwide from 1990 to 2022 (Statista, 2023)

Conventional energy makes up 70% of the global increase in electricity generation in 2022, while renewable energy makes up 30%. The distribution of energy production rates breaks down as follows: The distribution of energy production rates is as follows: 2.4% for bioenergy, 4.5% for solar, 7.5% for wind, 15.2% for hydro, 0.4% for other renewables, 9.2% for nuclear, 22% for natural gas, 35.8% for coal and 3% for other fossil fuels (Fig. 2) (Statista, 2023).

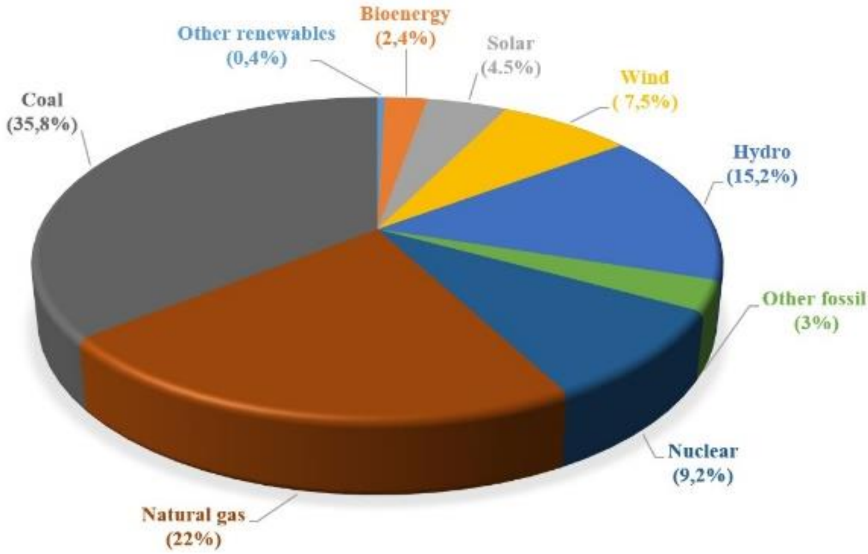

Figure 2. Distribution of Electricity Generation Worldwide in 2022 (Statista, 2023)

Since 2009, the energy industry has had a remarkable development in the total installed power capacity of Türkiye (Fig. 3). With the quick development, the total installed electricity power increased by 132% from 44761.4 MW in 2009 to 103809.3 MW in 2022 (EPİAŞ, 2024).

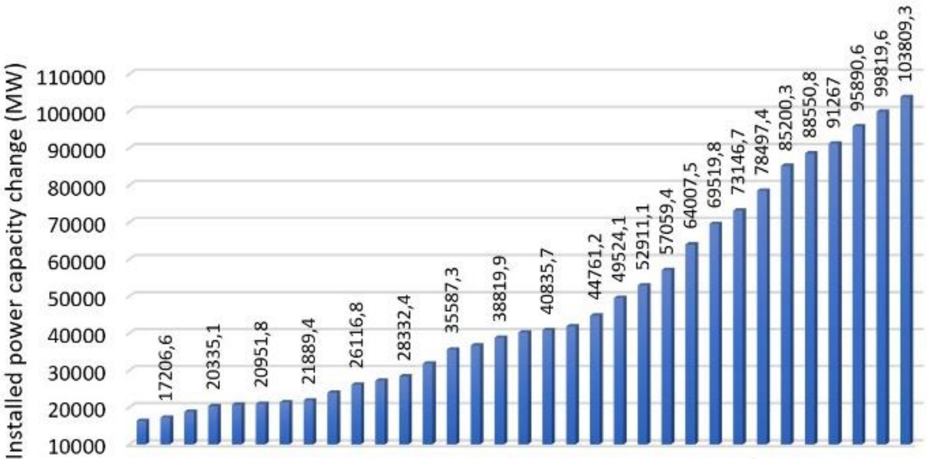

Figure 3. Installed Power Capacity Change by Years of Türkiye (EPİAŞ, 2024)

In the worldwide power generation distribution for 2022, conventional energy represented 70%, and renewable energy represented 30%. The distribution of energy production rates is as follows: bioenergy 2.4%, solar 4.5%, wind 7.5%, hydro 15.2%, other renewables 0.4%, nuclear 9.2%, natural gas 22%, coal 35.8%, and other fossil fuels 3% (Fig. 2) (Statista, 2023).

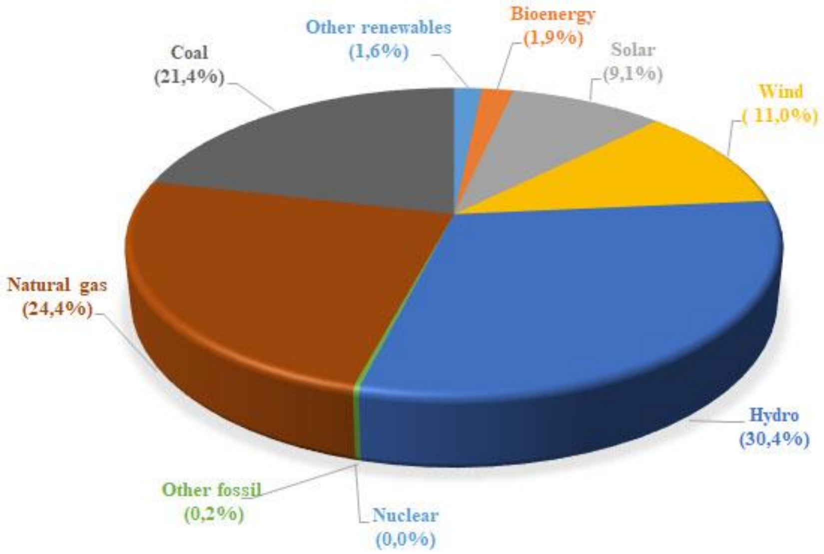

Figure 4. Distribution of Electricity Production in Türkiye in 2022 (TEİAŞ, 2023)

The percentage of renewable energy is high (54%) in relation to the global power generation rate, with hydroelectric energy accounting for the highest part (30.4%) (TEİAŞ, 2023). These statistics all highlight how crucial hydroelectric power is to Türkiye. In 2022, 30.4% (31571.5 MW) of Turkey's total electricity production was produced from HPPs. Hydroelectric energy makes up 56.3% of the total amount of renewable energy produced. Hydroelectric power plant production constitutes 22.4% of the total hydroelectric energy production. Additionally, hydroelectric plants on rivers constitute 8% (8296.3 MW) of this production. Among the different types of power plants, hydroelectric power plants (HPP), considered the primary source of renewable energy, play an important role (EPİAŞ, 2024).

Renewable energy provides an important percentage of worldwide power generation at 54%, with hydroelectric energy being the largest share at 30.4% (TEİAŞ, 2023). These statistics emphasize the significance of hydroelectric power in Türkiye. In 2022, hydroelectricity generation was the largest share of Türkiye's total power generation, producing 31,571.5 MW (30.4%). Hydroelectricity constitutes 56.3% of the total renewable energy generated. Hydroelectric energy production accounts for 22.4%, as does the entire hydro-based energy output, facilitated by 141 dams. Hydroelectric energy production is supplied by HPPs on rivers, accounting for 8% (8296.3 MW). Among the diverse types of power plants in our country, HPP, as the main renewable energy source, has an important position (EPİAŞ, 2024).

In the worldwide electricity generation ratio for 2022, conventional energy constituted 70%, while renewable energy accounted for 30%. The distribution of energy production rates is as follows: bioenergy 2.4%, solar 4.5%, wind 7.5%, hydro 15.2%, other renewables 0.4%, nuclear 9.2%, natural gas 22%, coal 35.8% and other fossil fuels 3% (Figure 2) (Statista, 2023).

MATERIAL AND METHODS

Study area

The study area is located on the Isparta N24-d1 sheet of the Turkish topographical map index at a scale of 1:25,000, within the boundaries of Antalya province in the Mediterranean Region. It is located in the Universal Transverse Mercator (UTM) WGS84 36th zone, with coordinates of 30° 00' 06"-30° 01' 57" east and 37° 09' 28"-37° 11' 13" north. The HPP Project is located in southern Türkiye, specifically between Antalya province and the Korkuteli district, adjacent to Sülekler Village to the west of both the district and the village (Fig. 5). The closest communities are Başpınar Village, located 1.5 km to the north and Sülekler Village, situated 8 km to the southeast of the project area. The water intake structure is located on Korkuteli.

Climate features

Despite the project area's approximate 50 km air distance to the Mediterranean Sea, the high elevation mountain ranges in between significantly reduce the impact of the sea. The climate is generally continental: hot and dry in the summer and snowy and cold in the winter.

Hydrology

The Korkuteli HPP project will be constructed on the Korkuteli Stream, which is charged by many springs located west of Başpınar village and runs in several directions. The explanation for this phenomenon is the existence of several karstic water springs in the northern section of the basin where limestones occur (Çakmak et al., 2021). Korkuteli Stream is mostly charged by the Değirmen and Sarısu Streams, both originating in Taşkesiği, while Değirmendere Stream flows southwest, generating a meandering flow.

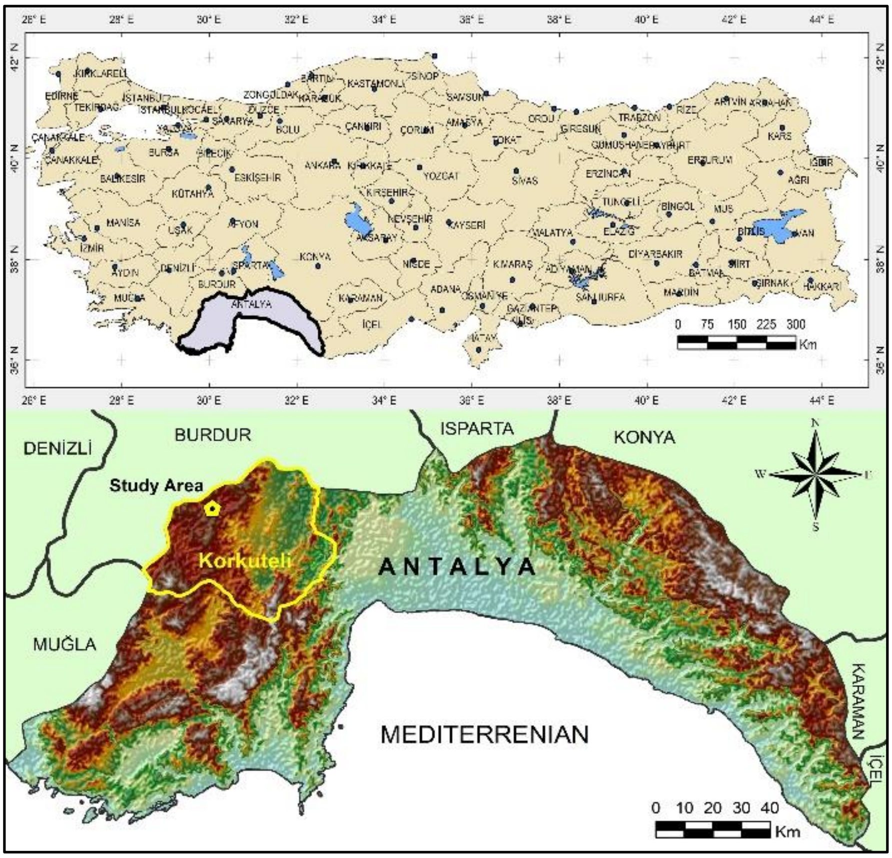

Figure 5. Study Area Location Map

The Sarısu, İbizler, Adaçay, Meneviş, Ciltas, and Ecerekler Streams converge with the Değirmendere Stream to sustain its course. The stream is designated as Korkuteli Stream after its confluence with Sarısu Stream in the Varsak Plateau and subsequently with Değirmen Stream. The design of the plant's water intake system adheres to the convergence of these streams. The Korkuteli Stream flows southeast via the Salamut Strait and into the Korkuteli Dam after the intake construction.

The catchment area in the Korkuteli Stream regulator field is 123.23 km². The HPP structure lies approximately 2.5 km beyond this point. The catchment area where the HPP structure is located was measured as 127.51 km². Korkuteli Stream - Salamur Strait Flow Observation Station (FOS) No. 09-011 is located approximately 300 m downstream of the HPP structure and Korkuteli Stream reaches Korkuteli Dam in the north of Korkuteli district after 8 km. After the dam outflow, it combines with Kargalık Stream downstream of the district and is called Marzuman Stream. Then it reaches the Bıyıklı sinkhole on the upper plateau of Antalya via the Korkuteli Diversion Channel and combines with the Düden Stream through the sinkhole.

A fish farm is located between Korkuteli Regulator and HPP, around 300 m downstream of the regulator structure. The fish farm uses 40 liters per hour of water from the Korkuteli Stream. However, there are water intake stations for agricultural lands with water rights shared by the regulator and HPP. The fish farm recycles the water and uses it to irrigate agricultural land. The Korkuteli HPP Project will obtain its water from the Korkuteli Stream. The General Directorate of State Hydraulic Works created Korkuteli Stream-Salamur Strait FOS No. 09-011, which is currently operational. No. 09-011 The Korkuteli Stream—Salamur Strait FOS, located at a height of 1190 m, has a 44-year history.

Environmental flow

The first condition for streams to maintain their ecological characteristics is to have sufficient water flow throughout the year. This flow rate is called 'life water, compensation water, environmental flow, ecological flow, and ecosystem water requirement'. Besides being natural habitats, streams are also necessary for many other uses. Determining the "environmental flow" amounts is crucial to preserving the ecological characteristics of streams and fulfilling each purpose.

The Korkuteli HPP project area lacks both protected areas and endemic species. For these reasons, wetted perimeter method (WPM), flow duration curve method (FDCM), and base flow method (BFM) were used to determine the environmental flow.

Wetted perimeter method (WPM)

WPM assumes that there is a direct relationship between a river's wetted environment and its fish habitat. This approach is appropriate for rectangular or trapezoidal sections in flat riverbeds (Zhang et al., 2021; Parker et al., 2004). WPM can only determine the minimal environmental flow. In the case of water removal from the river, this method cannot determine the river's impact, its severity, or its extent (Reinfelds et al., 2004; Marotz & Muhlfeld, 2000; King et al., 1999).

In critical sections where water velocity and water depth decrease with the widening of the river bed, WPM uses the relationship between the wetted environment and flow velocity. The non-dimensional wetted perimeter (WP/WPmax) and non-dimensional flow rate (Q/Qmax) are calculated using the basic section values (Fig. 6). The dimensionless flow value at the graph's break point determines the flow rate, which we call the environmental flow rate.

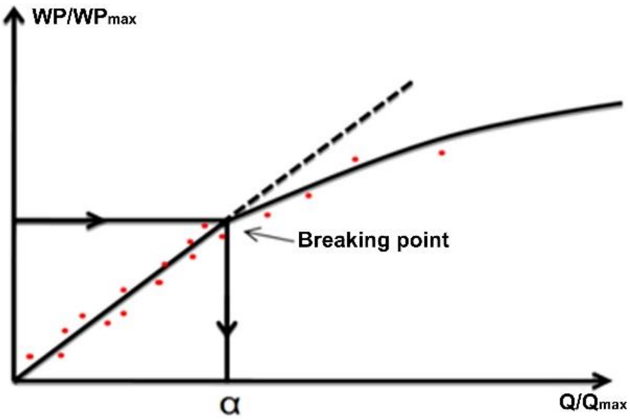

Figure 6. Dimensionless Wetted Environment (WP/WPmax)-Dimensionless Flow Rate (Q/Qmax) Relationship

The flow duration curve method (FDCM) was developed based on long-term daily flow data. FDCM is a statistical approach based on the determination of the cumulative frequency distribution of flow values passing through the bed at a selected time (Rai & Jain, 2022; Searcy, 1959). Formulate the FDCM in accordance with daily flows to ensure it provides the appropriate methodology. The flow continuity curve facilitates the calculation of yearly water volume based on the proportion of time that a certain flow traverses the transmission line and the peak flow rate. Figure 7 provides a typical flow-continuity curve.

Base flow method (BFM)

A stream defines a base flow as a low flow. This flow contains both river discharge and more often groundwater discharge. This flow does not include spring discharges caused by rainfall and snowmelt. The base flow was calculated using long-year monthly average flow rates observed at the Korkuteli Stream.

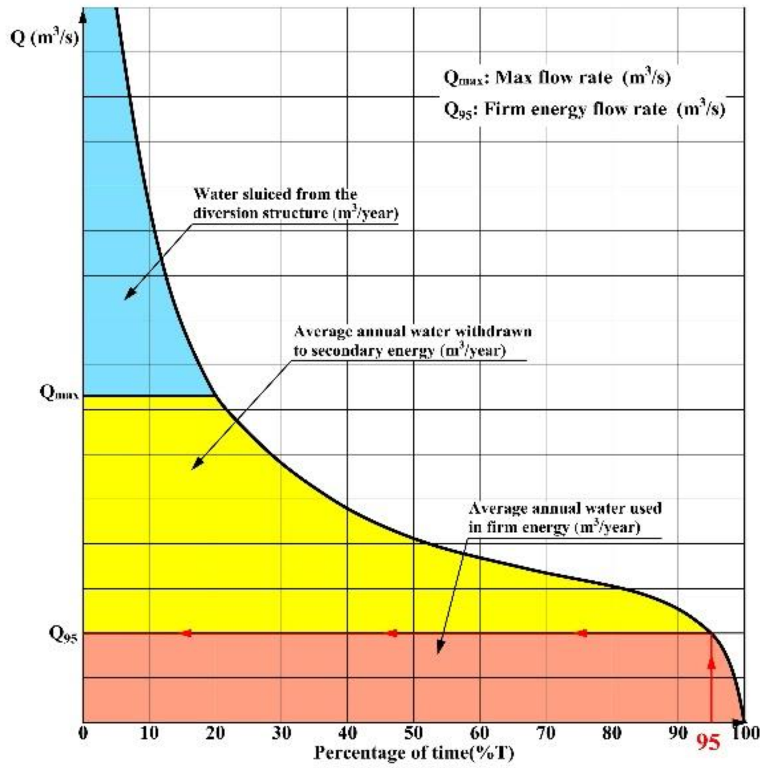

Figure 7. A Typical Flow Duration Curve

RESULTS AND DISCUSSIONS

Stratigraphy

The northwest region of the Gulf of Antalya is home to the study area. The research region encompasses the allochthonous Lycian Nappes, Yesilbarak Nappes, and the Eocene-aged Varsakyayla Formation (Senel, 1997). The summit displays Quaternary-aged alluvium and slope debris. The Jurassic-Cretaceous period's limestones make up the majority of the research region. The limestones include dolomite, dolomitic limestones, enormous thick-bedded limestones, and thin-bedded pelagic limestones, arranged from bottom to top. In the middle regions of the basin, Eocene-aged clastic rocks including a series of claystone, marl, limestone, and sandstone are present. To the south, Miocene-aged sandy-clay limestone, conglomerate, and marl lithologies are present.

Hydrogeology

The study area is situated within the Korkuteli Plain basin. The basin contains autochthonous Beydağları rocks in the south and east, as well as allochthonous Lycian Nappes rocks in the north and west. The Orhaniye formation and the Dutdere limestone are the research area's permeable units with aquifer features. Permeable units include the limestones of the Yeşilbarak Nappe's Yavuz Formation and the Yeleme olistostrome. The impermeable units are the Yavuz, Elmalı, and Varsakyayla formations. The aquifer units in the study area discharge their waters from springs.

Hydrology

The Thiessen Polygon method has determined the catchment area of the HES Project, as represented by meteorological stations (MS). Başpınar (Yeleme) MS represents 98% of the watershed area, while Sertaç (Kemer) MS represents 2%. Başpınar (Yeleme) MS has an elevation of 1500 m and according to 41 years of observations from 1963 to 2003, the annual average precipitation was calculated to be 457.9 mm. The monthly average precipitation in the project area and its surroundings has been calculated as 410.9 mm.
The yearly mean evaporation has been calculated for the Korkuteli MS (Class A Pan) and Yeleme MS within the study's area. Korkuteli MS, located at a height of 1014 m, recorded an average evaporation rate of 1192.5 mm over a 21-year observation period from 1984 to 2004. The mean annual temperature of Korkuteli MS has been determined to be 12.5 °C, derived from 34 years of data collected between 1969 and 2003. The flow measurements of Korkuteli Stream were derived from 44 years of data, covering from 1964 to 2007, obtained at Salamur Boğazı FOS (09-011). The Korkuteli Stream has an average annual discharge of 0.999 m^3/s and an annual average flow volume of 31.5 hm^3.

Environmental flow

One of the most important studies in HPP projects is determining the environmental flow. This study calculated the environmental flow for Korkuteli HPP using three different methods.

Wetted perimeter method (WPM)

Field studies led to the preparation of the stream's cross-sectional profile at the most suitable location between the regulator and the HPP. The area in question is located upstream of the planned water intake point. Table 1 displays the threshold cross-sectional parameters calculated for this location.
Eq. 1 presents the mathematical relationship between the dimensionless flow rate and the dimensionless wetted perimeter.

$$\left(\frac{WP}{WP_{max}}=\right) 0.9395 \left(\frac{Q}{Q_{max}}\right)^{0.3225} \tag{1}$$

Table 1. Korkuteli HPP Regulator Cross-Section Parameters and Dimensionless Wetted Perimeter and Dimensionless Flow Rate Value

Q (m^3/s)	Wetted Perimeter (WP) (m)	WP/WP_{max}	Q/Q_{max}
0.027	0.760	0.500	0.130
0.028	0.780	0.513	0.135
0.032	0.800	0.526	0.154
0.035	0.840	0.553	0.168
0.037	0.860	0.566	0.178
0.040	0.880	0.579	0.192
0.048	0.900	0.592	0.231
0.058	0.920	0.605	0.279
0.062	0.940	0.618	0.298
0.073	0.960	0.632	0.351
0.077	0.980	0.645	0.370
0.081	1.000	0.658	0.389
0.083	1.020	0.671	0.399
0.087	1.040	0.684	0.418
0.088	1.060	0.697	0.423
0.095	1.080	0.711	0.457
0.110	1.100	0.724	0.529
0.115	1.120	0.737	0.553
0.122	1.160	0.763	0.587
0.135	1.220	0.803	0.649
0.146	1.260	0.829	0.702
0.160	1.300	0.855	0.769
0.175	1.420	0.934	0.841
0.180	1.480	0.974	0.865
0.208	1.520	1.000	1.000

Eq. 1 defines WP as the wetted perimeter, WPmax as the maximum wetted perimeter, Q as the flow rate, and Qmax as the maximum flow rate. By equating the first derivative of the previous formula to 1, the dimensionless flow value (Q/Q_{max}) at the breaking point, where the slope of the curve changes, was determined to be approximately 17%. The calculation results in the environmental flow (Q_{ef}) value for the Korkuteli HPP Regulator, as shown in Table 2.

Table 2. Calculated Environmental Flow Amount for Korkuteli Regulator (m^3/s)

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.
Mean	0.756	0.800	0.870	0.986	1.109	1.358	1.480	1.348	1.083	0.811	0.688	0.702
Q_{ef}	0.129	0.136	0.148	0.168	0.188	0.231	0.252	0.229	0.184	0.138	0.117	0.119
Q_{ef}(%)	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00

Flow duration curve (FDC)

The Korkuteli regulator developed its FDC by utilizing long-term monthly averages (Fig. 8). The Q25, Q50, Q75, and Q95 values were calculated from the FDC derived from the measurements taken at the Korkuteli Regulator. The Korkuteli Regulator FDC records flow rate values of 0.18 m3/sec 95% of the time, 0.39 m3/sec 75% of the time, and 0.57 m3/sec 50% of the time. Additionally, the system records a flow rate of 0.57 m3/sec 25% of the time and calculates a flow rate of 0.81 m3/sec and 0.016 m3/sec 100% of the time. The persistence of the aquatic habitat within the ecological system under natural conditions suggests that a long-term tolerance for a flow rate as low as 0.016 m3/s is possible.

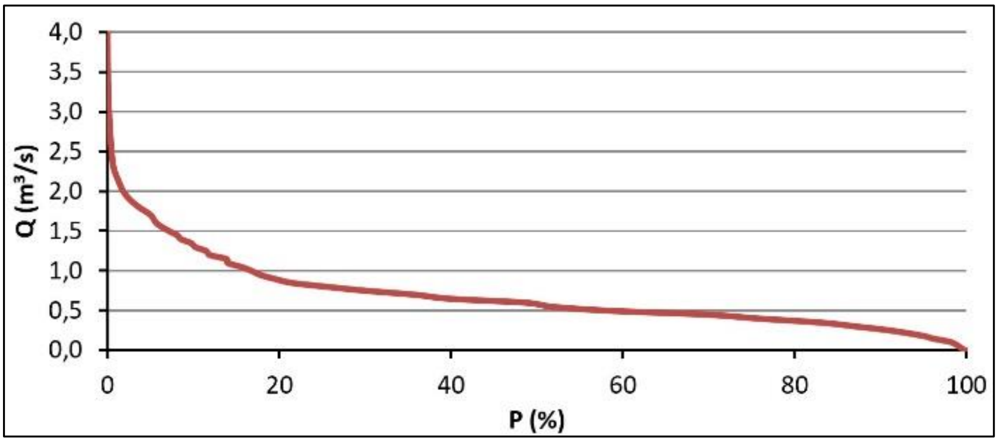

Figure 8. FDC Graph of Korkuteli Regulator

Base flow method (BFM)

The graphs showing the time-dependent variation of observed flows indicate that base flow occurs in October, November, December, July, August, and September. Furthermore, we observe higher flow values during the six-month interval from January to June. As a result, we determined the long-term base flow value at the Korkuteli HPP regulator location to be 0.77 m^3/s. The unit hydrograph of the stream was constructed and the base flow value was determined from this graph (Table 3).

Table 3. Base Flow Quantities Calculated at Korkuteli HPP Regulator Location

Months	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**
Q_{mean}	0.756	0.800	0.870	0.986	1.109	1.358	1.480	1.348	1.083	0.811	0.688	0.702
Base Flow Method (Q_{ef})	0.771	0.771	0.771	0.771	0.771	0.771	0.771	0.771	0.771	0.771	0.771	0.771
Q_{ef} (%)	101.96	96.36	88.67	78.16	69.55	56.76	52.08	57.21	71.22	95.05	112.08	109.80
Q_{mean}-Base Flow Method	-	0.029	0.099	0.215	0.338	0.587	0.709	0.577	0.312	0.040	-	-

The amount of environmental water to be discharged from the Korkuteli HPP regulator each month was determined using several methodologies.

The wetted environment approach served as the foundation for determining the environmental flow for Korkuteli HPP. The monthly environmental flow to be discharged into the stream was calculated (Table 4). To ensure the continuation of natural life and ecosystems, the volume of water discharged downstream must be no less than 10% of the average flow recorded throughout the past decade of the project. If the stream flow is below 10% of the average flow over the last decade, it should be entirely discharged. The wetted environment approach determined the environmental flow to be 17% of the average flow. Consequently, we determined that the wetted environment technique accurately reflects the natural flow conditions in the study area.

Table 4. Monthly Environmental Flow Amounts That Should Be Released to The Stream Calculated by Wetted Perimeter Method at Korkuteli Hpp

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.
Qmean (m^3/s)	0.756	0.800	0.870	0.986	1.109	1.358	1.480	1.348	1.083	0.811	0.688	0.702
%10 of LTMFA*	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099
Qef	0.129	0.136	0.148	0.168	0.188	0.231	0.252	0.229	0.184	0.138	0.117	0.119
Qef (%)	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
Qmean-Qef	0.63	0.66	0.72	0.82	0.92	1.13	1.23	1.12	0.90	0.67	0.57	0.58

* LYAAF: Long-Term Monthly Flow Averages

Environmental impact of HPP

HPPs are energy production facilities that have the least harmful effects on the environment. Such plants do not create air, water, soil, noise pollution, solid waste, and radioactive leakage hazards. Therefore, we analyse the effects of these plants on the basins where they collect water, not the plants themselves.

There will definitely be a change in the quality of the water coming out of the power plant. The water, originating from a high elevation, swiftly enters the turbine and exits the power plant at a low temperature. The tailwater channel receives the cold water, allows it to wait and then discharges it into the stream bed. Thus, water quality can be eliminated and the water can be made suitable for aquatic organisms that cannot adapt to cold environments. Additionally, shortly after exiting the HPP, the plant's water will attain the appropriate water quality values. The construction of the regulators has led to some changes in the natural nutrient cycle downstream. Regulators significantly change the amount and duration of natural water flow in the stream. Therefore, the amount of flow directly influences the existence of species in their natural systems.

Surface flow contributes significantly to stream flows in the study area. Considering the hydrogeological characteristics of the geological units around the stream and the slope of the stream bed, their contribution to the charging of the stream is quite limited. In some extremely dry years in the study area, the flow in the bed of the stream decreased to 0.071 m^3/s monthly. This value corresponds to approximately 7.1% of the 44-year average flow (0.999 m^3/s). The long-term continuity of the biological and ecological structure suggests that we can tolerate this short-term drought.

In the study area, the sedimentary units surrounding the stream have very high groundwater storage and transmission properties. Despite this, there is no natural groundwater discharge point in the HPP area. Therefore, there is no significant interaction between surface and groundwater.

CONCLUSION

Determining the volume of water to extract from and discharge into the natural environment is essential in HPP. Mistakes in these computations might result in irreversible issues and damage. The amount of environmental flow must be calculated properly and precisely using an ecologically sustainable method.

This research assessed the environmental effect and flow rate of the Korkuteli HPP, situated in the Korkuteli district of Antalya province. The subject area was analysed both stratigraphically and hydrogeologically. Upon evaluating the lithological units and hydrogeological characteristics, it was concluded that there would be no adverse effects on the hydropower plant and the environment. The data on precipitation, evaporation, and temperature in the study region were analyzed. The majority of precipitation occurs during the spring and winter months. Winter snowfall does not influence flooding. Furthermore, winter snowfall facilitates resource replenishment via melting throughout the spring months.

The calculation of water potential at the water intake structure used the daily average flow data from Korkuteli Stream-Salamur Strait FOS No. 09-011. The annual average flow rate was determined to be 0.999 m^3/s and the yearly average flow was computed at 31.50 hm^3. The spring discharge prevented Korkuteli Stream from transporting excessive silt. Furthermore, field investigations were conducted on the streambed to validate this condition.

Three different methodologies were used to ascertain the amount of environmental flow. Of the three ways, the wetted environment method was selected as the reference. The wetted environment approach suggested that the monthly environmental discharge into the stream should equal 17% of the average flow. The dimensions of the Korkuteli HPP study area, the lack of lateral surface flow inside the project zone, the transportation of water from an external basin by canal, and geomorphological aspects were assessed. The studies determined that the HPP project would not adversely affect hydrology, ecology, or geomorphology.

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