

Case Study

Evaluation of environmental impact assessment and mitigation strategies for Gulpur hydropower project, Kotli, Pakistan

Asim Qayyum Butt^{1,2,3} · Donghui Shangguan^{1,2,3} · Yongjian Ding^{1,2,3} · Abhishek Banerjee¹ · Muhammad Ahsan Mukhtar^{1,2,3} · Khurram Taj⁴

Received: 13 October 2023 / Accepted: 4 March 2024

Published online: 18 March 2024

© The Author(s) 2024 [OPEN](#)

Abstract

Environmental Impact Assessment (EIA) became mandatory in Pakistan in 1983 with the passage of the Pakistan Environmental Protection Ordinance. The Sustainable Development Goals were incorporated into Pakistan's national development strategy, making it the first country in history to do so. The study is based on evaluating the mitigation strategies and environmental impact assessment at the Gulpur Hydropower Project (HPP), Kotli, AJK, which uses the Poonch River's water resources to generate power and has a design capacity of 100 MW using the EIA documentation of Gulpur HPP. In addition to making additional observations and reviewing the literature, the study looked at Mira Power Limited's EIA reports. The possible effects, as well as the Government's and MPL's mitigating actions, were examined by the authors. EIA procedures at the Gulpur HPP considered several laws, including the Pakistan Environmental Protection Agency, AJK Wildlife Ordinance of 2013, the Land Acquisition Act of 1894, and Laws Regulating Flow Releases for Hydropower Projects. Projects using hydropower in delicate areas carry a high risk. Given the thorough analysis of the hazards in this instance, it is evident that the EIA had a significant impact on the project's design. The authors concluded that there are no negative environmental effects of the construction of hydropower projects in the concerned area and that all potential effects and compensation were handled legally and efficiently. The study suggested that all hydropower projects in Pakistan undertake environmental impact assessments.

Article Highlights

- Evaluating the mitigation strategies and environmental impact assessment at the Gulpur Hydropower Project.
- EIA procedures at the Gulpur HPP considered several laws, including the Pakistan Environmental Protection Agency.
- The development of hydropower projects in the affected area had no negative environmental effects, and any potential effects or compensation were handled lawfully and effectively.

Keywords Sustainable development goals · Environmental impact assessment · Hydropower · Environmental protection agency · Potential effects

✉ Donghui Shangguan, dhguan@lzb.ac.cn | ¹State Key Laboratory of Cryospheric Science, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730000, China. ²University of Chinese Academy of Sciences, Beijing 100049, China. ³China-Pakistan Joint Research Center On Earth Sciences, CAS-HEC, Islamabad 45320, Pakistan. ⁴NUST Institute of Civil Engineering, National University of Science and Technology, Islamabad 45320, Pakistan.



Abbreviations

EIA	Environmental Impact Assessment
PEPO	Pakistan Environmental Protection Ordinance
SDG	Sustainable Development Goals
HPP	Hydropower Project
AJK	Azad Jammu and Kashmir
MPL	Mira Power Limited
GHG	Greenhouse Gas
SHP	Small Hydropower
SEA	Strategic Environmental Assessment
WAPDA	Water and Power Development Authority
EPA	Environmental Protection Agency
ADB	Asian Development Bank
NEQs	National Environmental Quality Standards
LARP	Land Acquisition and Resettlement Plan
EFlow	Environmental Flow
PPE	Personal Protective Equipment
NHA	National Highway Authority

1 Introduction

Earth and environmental sciences have a strong connection between them, and it gets the town's talk when humans change the natural ecosystem during their development. Pakistan, a developing nation with the sixth-largest population in the world, has a wealth of potential for sustainable energy resources [1], having geographic boundaries extending over 1600 km from southwest to northeast. It is unfortunate that a significant portion of this hydroelectric potential remains unrealized. Pakistan currently has about 10,127 MW of installed hydropower capacity, of which 5790 MW are in Khyber Pakhtunkhwa province, 2386 MW are located in Azad Jammu and Kashmir (AJK) region, administrated by Pakistan, 1802 MW are located in Punjab province, and 151 MW are located in Gilgit Baltistan province. Similar projects are currently being constructed across the country, with a total estimated power generation of 8518 MW from hydropower [2].

Hydropower accounts for more than 16% of the global electricity consumption, making it the largest contributor to renewable energy with a share of 71%. Several countries have expanded their renewable energy portfolios, including significant investments in large-scale hydropower projects, in order to achieve international carbon reduction targets [3, 4]. The implementation of ongoing hydroelectric projects has the potential to increase the global hydropower capacity by 73%, and in some cases, even up to 100%, according to certain estimates. The development of hydropower has environmental consequences that can range from local to regional in scale [5], while providing a flexible and renewable energy source to complement intermittent sources like solar and wind, hydropower can also lead to alterations in river ecosystems [3]. While the state's economy reaps advantages from the growth of hydropower capabilities, it concurrently inflicts environmental damage and triggers numerous conflicts regarding the redistribution of land and water resources [6, 7]. A major issue is the insufficient participation of the public in the process of building dams, particularly for local communities that are directly affected by hydropower initiatives [8–10]. Countries have a variety of policies in place to evaluate the environmental impacts of operation, hydropower development, and mitigation measures [11]. A universal characteristic of all regulations, albeit with varying procedures across different nations, is the necessity of an environmental impact assessment (EIA) [12, 13]. Authorities may face challenges in ensuring that Environmental Impact Assessment (EIA) processes can keep pace with the rapid and dynamic development of hydropower in some areas or implemented at all in certain circumstances.

Although hydropower offers a versatile and renewable energy source that can be used to complement the intermittent nature of other energy sources, such as solar and wind [14, 15] hydropower generation results in both regional and local environmental impacts, including alterations to river ecosystems [16, 17]. Owing to its particular attributes and dedication to sustainability, hydropower has become a powerful tool in the global battle against energy-related issues [18]. Acknowledging the underlying depletion and finiteness of resources [19], it offers an opportunity to meet the continuous energy demands resulting from economic and population growth while upholding environmental standards (particularly in light of global warming, climate change concerns and greenhouse gas (GHG) emissions,) and concurrently

improving social welfare by providing electricity to undeveloped and remote areas [20]. To meet global carbon reduction targets, many countries have expanded their renewable energy portfolios [21], making significant investments in the construction of large hydropower plants [22, 23].

The Environmental Impact Assessment (EIA) is an excellent example of recent legislation that aimed to uphold a positive link between the environment and development. EIA was made mandatory in Pakistan in 1983 by the Pakistan Environmental Protection Ordinance (PEPO). EIA requirements were made more stringent by law in 1997 with the creation of the IEE/EIA Review rules of 2000 and the Pakistan Environmental Protection Act of 1997 (PEPA'97), which replaced PEPO. Additionally, several regulations have been created to support the national EIA system's implementation. Other notable guidelines are the EIA policies for oil and gas investigating in environmentally sensitive regions from 1997, the EIA guidelines from 1986, the EIA energy sector directions from 1992, the sub-sectoral guidelines from Khyber Pakhtunkhwa EPA for twenty-two sectors, and the sub-sectoral guidelines from Balochistan EPA for three sectors. Historic projects like the oil and gas extraction in Kirthar National park have raised the bar for EIA, but they have also demonstrated the need for further improvements in Pakistan [24].

Looking at the vast amount of EIA literature currently available, it is clear that a multitude of varied contributions have been made to assess the effectiveness of national Environmental Impact Assessment (EIA) systems [25, 26]. Well-known comparative while transnational research has been conducted by the United States, Canada, and the European Union [27–29]. Previous attention has been directed towards the technical and scientific substance of EIA reports, as well as their overall caliber. The significance of conducting environmental impact evaluations for both large-scale as well as small scale hydropower projects has been emphasized by numerous scholars worldwide. The study by Erlewein [30] set out to investigate the structural shortcomings of environmental consideration for development of hydropower in Himachal Pradesh, India. They stated that traditional methods of environmental assessment are finding it harder and harder to keep up with the speed and intensity of development policies for hydropower expansion. Utilizing a qualitative methodology comprising on-site observations, consultations with ecological experts, and document reviews, the study argues that the prevailing approach of restricting Environmental Impact Assessments (EIAs) to individual projects fails to acknowledge the broader and more substantial impacts of widespread hydropower development. Hence, the capacity of the Strategic Environmental Assessment (SEA) concept to effectively tackle present concerns was thoroughly examined. Similarly, a Research by Botelho et al. [31] has shown that benefit transfer should not be employed due to the distinct and varied impacts of each hydropower plant. This conclusion is based on review of evaluation studies on the environmental consequences of hydropower and the analysis of specific cases regarding the various environmental impacts associated with hydroelectric power. Their research emphasized the significance of employing a case study methodology to determine the order of importance for alternative hydropower-generating facilities. Ultimately, they demonstrated that choice experiments were especially suitable for assessing the identified environmental effects, as they were relevant for policy design.

The combined environmental effects of twenty seven small hydropower facilities and three major hydropower projects were investigated by Bakken et al. [32]. The findings hinted at a precarious tendency that large-scale hydropower projects have fewer adverse effects than numerous small-scale ones, but they are inconclusive due to hazy data and a weak methodological foundation. They concluded that it was reasonable to assume that some large hydroelectric power developments would generate electricity at a lower cost to the environment than many small projects, which must be taken into consideration when achieving the government's renewable energy goals. Other advantages, such as the availability of regulated power, were also taken into account. In another study, [33] focused on the environmental impact assessment of the small hydropower (SHP) plant. The environmental impact of a Small Hydropower (SHP) plant in Spiské Bystré, Slovakia was assessed. The various options for a specific hydraulic structure were also assessed quantitatively in terms of the characteristics, significance, and duration of the effects. The work's conclusion suggested measures to lessen the negative effects and included the choice of the best alternative for the evaluated construction. The study's advantage was in emphasizing how crucial it is to evaluate the environmental effects of construction during the planning stage. The researchers concluded that minimizing the adverse impact of construction on the environment is considerably more challenging than implementing preventive measures, so it is crucial to consider this when planning any proposed activities. Similarly, [34] acquired the results of a year-long investigation aimed at assessing the quality of environmental impact assessments finished for small hydroelectric plants in Portugal. Every EIA Report that was used as the basis for effective EIA procedures for this kind of small-scale project under the national EIA laws of the preceding two decades was carefully examined. These projects, which are frequently hidden from view by the public and the media and are situated in remote regions upstream of secondary rivers, are likely to have a significant negative impact on the environment, especially on the aesthetic value and character of nearby landscapes and on pristine ecological habitats.

And yet, they are frequently regarded as green initiatives created to generate energy without emissions. The literature review on comparable research projects completed in other EU countries helped shape the design of the evaluation criteria. In a sizable portion of the cases, the evaluation exercise exposed several technical and methodological flaws. Most of Portugal's EIA practices' strengths and weaknesses share characteristics with those seen in other national EIA systems within the EU. After all, converging results are expected from two EIA Directives over twenty years. The significance and scope of the particular issues identified as well as the advantages of the chosen solutions.

The perception of the four Sustainable Harvesting Practices (SHPs) in India's Western Ghats by conducting semi-structured interviews involving local respondents was assessed by Jumani et al. [35] to have had an impact on socio-ecological circumstances. Following the primary interview data, respondent perceptions were compared with the expected baseline of assured impacts which had been sequentially validated with secondary data. They assessed the degree of knowledge about SHPs, perceived socioeconomic effects, influence on resource access, and effects on interactions between people and elephants. SHPs were not well known to the general public and promises of generating local electricity and jobs remained largely unfulfilled. The majority of respondents also experienced numerous unanticipated negative effects. They discovered a direct correlation between the development of SHPs and rising levels of conflict between humans and elephants. We recommend that policies about SHPs be appropriately revised in light of the discrepancy between assured and actual social impacts. In another study, [36] planned to use the hydroelectric plant environmental impact assessments (EIA) from 1990 to 1997 in Trentino, Italy. The goal of their research was to create an analysis that, starting with the unique characteristics of environmental projects, locations, and EIA studies, detects similarities in data structures using a particular index as well as multivariate statistical methods. RFS standards were examined for their primary environmental effects by Souza-Cruz-Buenaga et al. [37] while accounting for the various water uses particular to each dam site. Natural variations in river flows create a range of habitats and maintain the diversity and complexity of biological groups. As a result, the current study has important ecological, social, and economic ramifications because a sound evaluation of the RFS requirements guards against potential instability in biological communities and potential loss of biodiversity.

The objective of the study was to examine the Environmental Impact Assessment procedure adopted by the authorities and responses by the local community and stakeholders. The current study focused on analysis of the ecological resources, flora and fauna, describing the effects of the planned development, weighing their importance, and determining any lingering effects in the targeted region. The study included the documentation assessment by the relevant agencies, the potential impacts at the site and adopted mitigation measures raised during the EIA processes. The study highlights the importance of the EIA processes before any development project specifically the hydropower project in a country like Pakistan, where energy crises are already the talk of the town.

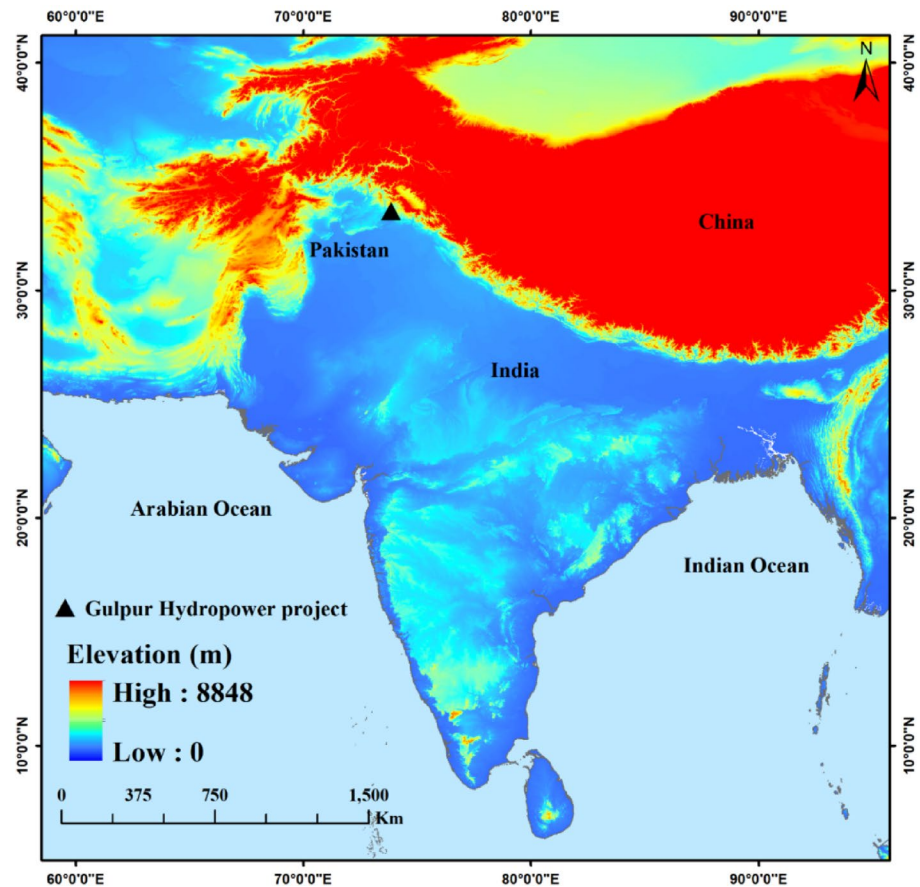
2 Methodology

2.1 Study area

The Poonch River's water resources will be used to generate electricity by the 100 MW planned capacity Gulpur HPP. The project location is situated around 9 km south of Kotli town in the Kotli district of Azad Jammu and Kashmir [38]. Situated around 167 miles from Islamabad, Pakistan. The project is situated roughly 28 km upstream of the Mangla dam reservoir. The study area is shown in Fig. 1. The Gulpur HPP is a run-of-the-river project with two Kaplan-type turbine units that have an average energy production of 436 Gwh. It is intended to generate 100 megawatts (130,000 hp). An average of 465 GWh of energy might be produced annually by the project [39]. One of the World Bank-funded projects in Pakistan, the Gulpur Hydropower plant is a component of the country's least-cost energy generation strategy. The project, which is located on the Poonch river around 170 km from Islamabad, is being developed by Mira Power, a division of the Korean business KOSEP. A \$17.2 million loan from British international investment was given in 2015 to help build the new 102-megawatt (MW) Gulpur hydropower plant, which can generate 465 GWh of electricity annually [40].

Based on an assessment of the mitigation strategies and environmental impact assessment, the study examines the Gulpur HPP, Kotli, AJK using documentation from the EIA, which generates power from the Poonch river and has a design capacity of 100 MW. Apart from examining existing observations and literature, the study also examined the EIA reports of Mira Power Limited (MPL) and other documentation by the Asian Development Bank. The potential consequences as well as the mitigating measures taken by MPL, and the government were analyzed. The Pakistan Environmental Protection Agency, the AJK Wildlife Ordinance of 2013, the Land Acquisition Act of 1894, and the Laws Regulating Flow Releases for hydropower projects were among the laws that were taken into consideration during the EIA procedures at

Fig. 1 Location of Gulpur hydropower project



the Gulpur HPP. The methodology also included the analysis of surveys responded by the stakeholders/local community, project influence area, regulatory and institutional framework, environmental flow assessment, and potential impacts and proposed mitigation measures including their implementation as shown in Fig. 2.

3 Analysis and observations

3.1 Poonch river

The upper basin of the Poonch river is formed by the steep slopes of the Pir Panjal range. The river is sharply descending and small until it reaches the foothills, when the gradient becomes less steep, and the river widens to accommodate multiple tributaries. The valley narrows once more in the vicinity of the gradient steepens (6.9–8.3 m/km) till Kotli and the Line of Control (LOC), after which it flattens out (3.7 m/km). The river empties into Mangla reservoir, which is located where the Poonch and Jhelum Rivers converge [38]. The summer months see the biggest flows of the Poonch river, which are caused by the monsoon rains and snowmelt. Lower Poonch summer water temperatures are close to thirty degrees celsius.

3.2 Project influence area

The Poonch river crosses the Line of control about 4 km upstream of the Madarpur village and enters Pakistani territory after leaving Indian territory. The river features several pools and riffles and is roughly 100 m wide at its widest point. The river also features steep banks that rise to a height of 1500 m above the water, as well as powerful rapids. Figure 3 elaborates on the project area of influence to showcase the construction options. This portion of the Poonch river is home to snow trout, *Schizothorax plagiostomus*, which migrates downstream from colder upstream waters throughout the winter. The economic usefulness of snow trout reflects its status as an endangered species. In this area, other frequently

Fig. 2 Methodology followed to complete the case study

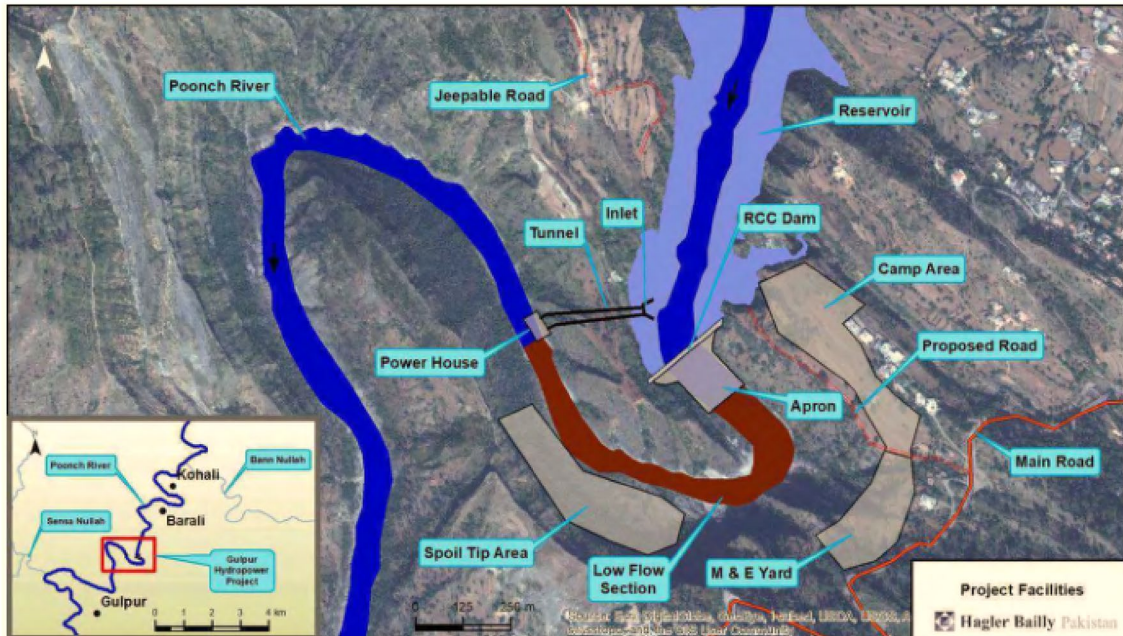
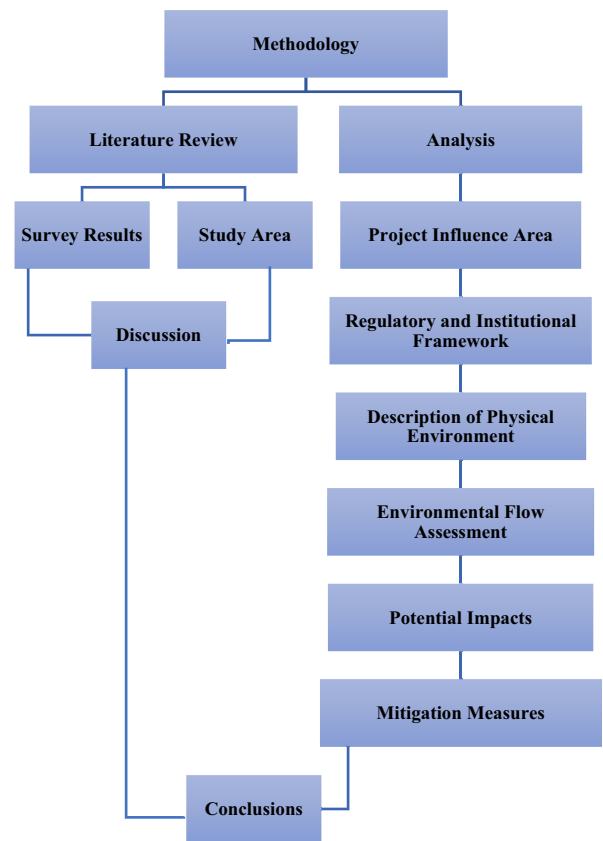


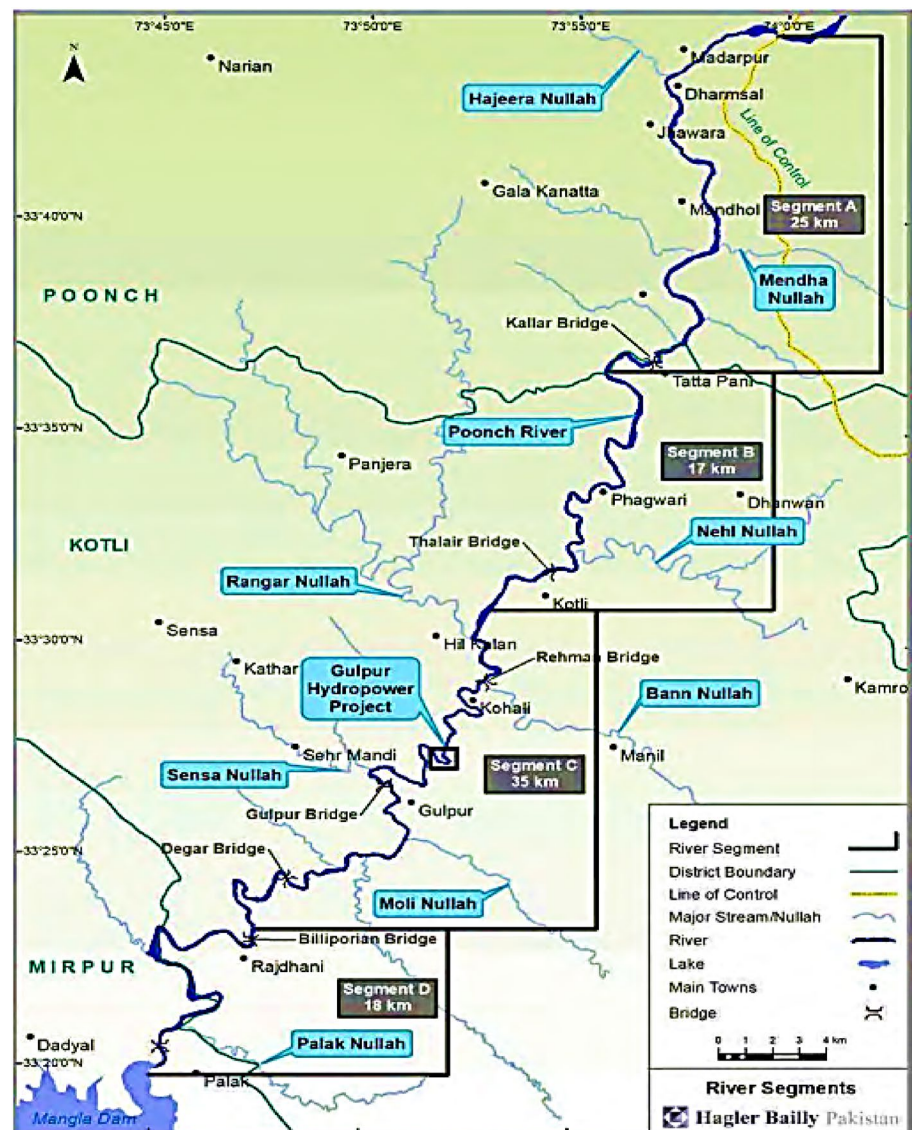
Fig. 3 Project brief-foot print to showcase the construction options [38]

occurring species include *Labeo dyocheilus*, *Garra gotyla*, *Crossocheilus latius*, and *Mahaseer Tor putitora*. This region has a large amount of illegal sand mining, especially close to Kallar bridge. At Titri note, there is a point of entry into Indian Administered Kashmir [38]. There are plenty of fish in this Poonch river segment A, and illicit fishing is frequently

conducted employing poisons, dynamite, and electrocution. There are many agricultural fields in this area due to the fertile ground.

In comparison to Segment A, Segment B's valley is larger, and its longitudinal gradient is shallower as shown in Fig. 4. It is typical for this section of the river to have braided channels. The river flows through a tight, steep valley in segment C before widening close to Gulpur. A slaughterhouse and a hydrological monitoring station operated by the Water and Power Development Authority (WAPDA) are situated close to Rehman bridge. Additionally, vultures feed in the rubbish disposal area. Upstream of Rehman Bridge, the Poonch River is joined by the Bann Nullah and the Rangar Nullah. The Mahaseer Tor putitota breeds in these tributaries. In this section of the river, common fish species include *Mastacembelus armatus*, *Glyptothorax stocki*, *Tor putitota*, *Botia rostrata*, *Clupisoma garua*, and *Crossocheilus latius*, which is typically found in the river's deep pools. With no access from a car, Hill Killan is the first village in this section. There are 480 people living in Hill Killan, living in about 80 households. This segment also involves a lot of sand mining because Kotli and Gulpur are major suppliers of construction materials. On this section lies a large settlement called Gulpur, which serves as a hub for the other little villages. In the Poonch valley, Gulpur is the second-biggest town after Kotli. Gulpur has about 6400 residents, living in 800 houses. The segment D exhibits a low longitudinal gradient and a comparatively large valley, as depicted in Fig. 4. This section of the river flows in a single channel, with deep pools and expansive flood plains being commonplace. The river empties into the Mangla reservoir at its terminus. Fish like *Tor putitora*, *Clupisoma garua*, *Botia rostrata*, *Glyptothorax stocki*, *Mastacembelus armatus*, *Parambassis ranga*, and *Chandanama* are frequently seen in this

Fig. 4 Designated river segments along Poonch river [38]



segment [38]. Near the Mangla dam, where both river and lake dwelling species are found, there is a greater diversity of fish species. Along this section of the Poonch River is the important village of Rajdhani. Sand mining is a current practice since Rajdhani is in high demand for building materials.

3.3 Regulatory and institutional framework

International treaties, ADB and IFC guidelines, as well as laws passed in Pakistan but approved by the AJK legislature, are among the applicable rules and guidelines for this ESIA. The main piece of legislation that governs protection of the environment in the state is the Azad Jammu and Kashmir Environmental Protection Act, 2000. IEEs and EIAs are the two categories of environmental evaluations that are covered by this Act. IEEs are performed for relatively minor projects with a relatively fewer significant impact than EIAs, which are performed for projects that may have a potentially “significant” environmental impact. In accordance with this law, an EIA was created and presented to the AJK Environmental Protection Agency (AJK EPA) for the Gulpur HPP. After reviewing the EIA, the AJK EPA approved the project’s construction.

The AJK EPA has accepted a set of environmental standards that the Pakistan Environmental Protection Agency published for carrying out environmental evaluations and environmental management of projects. The pertinent recommendations are: In 1997, the Pakistan Environmental Protection Agency released guidelines for the preparation and review of environmental reports. Additionally, in May 1997, the agency released guidelines for public consultation. Finally, in October 1997, the agency released guidelines for sensitive and critical areas. The following standards are outlined in the National Environmental Quality Standards (NEQs): The highest level of pollution (32 criteria) that can be present in emissions and liquid industrial effluents that are released into inland waterways. Maximum permitted pollutant concentration (16 parameters) in gaseous emissions from non-automotive sources. The highest permitted level of contaminants in vehicle exhaust gas emissions and vehicle noise emissions. Maximum noise level that cars are permitted to make. Ambient noise guidelines requirements for ambient air quality. In line with the concerns of the global community, the AJK Wildlife (Protection, Preservation and Management) ordinance 2013 aims to advance the social, cultural, economic, and ecological well-being of local populations. The Land Acquisition Act of 1894 addresses issues pertaining to the purchase of private land and other real estate that is situated on the land needed for the project. This law is complied with by the Land Acquisition and Resettlement Plan (LARP) created for the project. The Jammu and Kashmir Forest Regulations of 1930 (with revisions), also referred to as the Forest Law Manual, serve as the general rules for managing the forests in Azad Jammu and Kashmir. Pakistani maritime waterways are governed by the Fisheries Act 1897. The rules under wildlife legislation, however, take precedence over this legislation because the Poonch River is situated within a national park. The 1934 Factories Act: The act’s provisions pertaining to worker health, safety, and welfare, solid waste and effluent disposal, and damage to both private and public property are relevant. The rules governing the management and disposal of hazardous and poisonous products are also covered. The 1884 Explosives Act: It lays out guidelines for using, handling, and transporting explosives. The regulations must be followed by the contractors when they are blasting, quarrying, and doing other tasks [38]. Table 1 shows International treaties on biodiversity and Pakistan’s status.

3.4 Description of physical environment

The land formations in the Project region were formed near the base of the Himalayan Ranges as a result of tectonic activities that transpired after the Himalayas were formed. The middle Siwalik formations in the project area were formed by sedimentary deposits that were brought in by several drainage channels from the Himalayan Range’s uplift. The formation of rocks consist of highly folded beds of several kinds of sandstones, clay stones, and siltstones with nearly vertical

Table 1 International treaties on biodiversity and Pakistan’s status

Convention	Date of treaty	Entry into force in Pakistan
Convention on Biological Diversity (CBD)	1993	26 July 1994
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1975	19 July 1976
Convention on Conservation of Migratory Species (CMS)	1979	01 December 1987
Convention on Wetlands of International Importance especially as Waterfowl Habitat	1971	23 November 1976
Convention Concerning the Protection of the World Cultural and Natural Heritage (WHC)	1972	08 December 2011
Indus Water Treaty	1960	12 January 1961

dips. The only significant sources of air pollution in the project area are, for the most part, the roads that traverse the valleys of the Poonch river and the nullahs (tributary streams). The NEQS and IFC limitations were determined to be met by the measured amounts of sulfur dioxide, nitrogen dioxide, and carbon monoxide in ambient air. Additionally, it was discovered that the ambient PM₁₀ particle matter was within IFC and NEQS guidelines. Two towns close to the Project facilities—one near the planned position of the dam, the other near the planned location of the powerhouse—were the subjects of noise monitoring. The noise level was determined to be between 45 and 56 (dBA), mostly within the NEQS and IFC's stipulated limitations, with the exception of one place where the noise from the river's rapids increased the background noise level. Because of the noise from the river's turbulence, the nighttime noise levels typically surpassed the NEQS and IFC limitations. The project area is often in a subtropical and subhumid zone. It experiences chilly winters and mild summers. The snow-capped mountains of the Pir Panjal Range and the monsoon that occurs in July and August have a significant impact on the climate. The region receives 1237 mm of precipitation on average each year. There is a significant seasonal variance, though. The months of July and August see the most rainfall, with average precipitation of 266 mm and 271 mm, respectively. With an average of 24 mm, November experiences the least amount of rainfall. January to June has average monthly mean maximum temperatures ranging from 17.6 to 38.4 °C, while January to June sees average monthly mean minimum temperatures ranging from 4.8 to 24.9 °C. Figure 5 shows the climate and meteorology of the concerned area showing average monthly rainfall in mm and the evaporation in mm [38]. The project area's physiographic features cause the wind direction at the proposed powerhouse and camp site to be East/Westerly, whereas the wind direction at the proposed weir and batching plant location is mostly North/Easterly.

The forest department typically owns the land on the hills. There are settlements and agriculture on the high benches in mountainous regions. The government owns the beds of the rivers and nullahs (streams), as well as the nearby slopes. Because of this, the government-owned property will be home to the project's proposed dam, intake structure, which includes the power tunnel's intake portal, and powerhouse, which includes penstocks. It is suggested that the land on the raised benches close to the intended structures be secured for the construction camps and colony. The primary surface water resource in the project region is the Poonch river, which empties into Mangla reservoir after flowing alongside Kotli-Mirpur road. The Jhelum river's principal tributary is the Poonch river. About 3,800 km² make up the river's whole catchment area at the project dam location. Since 1960, WAPDA has kept a stream gauging station at the Rehman bridge on the Poonch river. Stream flows and suspended silt concentrations are measured. Situated around 5 km southeast of Kotli Town, Rehman rridge gauging station is situated just downstream of Bann Nullah. The Poonch river stream flow data at Rehman bridge, which is available as mean daily flows from 1960 to 2011, has been utilized to create an inflow time series. The mean monthly discharges, which are calculated using the mean daily flows, range from a minimum of 12 m³/s in January 1966 to a maximum of 830 m³/s in September 1992. The average monthly flows range from 279 m³/s in August to 41 m³/s in November [38]. Figure 6 shows the monthly flows and runoff of the Poonch river.

The Poonch river has an annual mean suspended sediment load of about 10.87 million tons. The majority of the riverbank deposits are made up of sand, even though the riverbed and banks include substantial morphological features including cobble and boulder beds. Sand makes up around 10% of the total suspended sediment load under current conditions, whereas silt and clay make up 90%, according to recorded sediment fraction distributions. The Poonch river

Fig. 5 Average monthly rainfall and evaporation in the study area

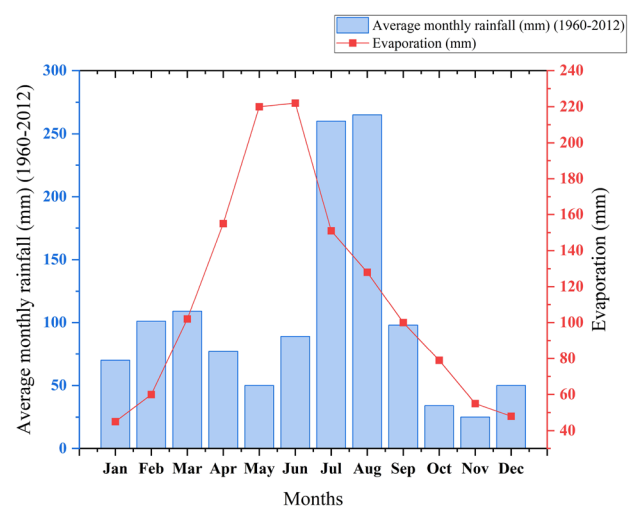
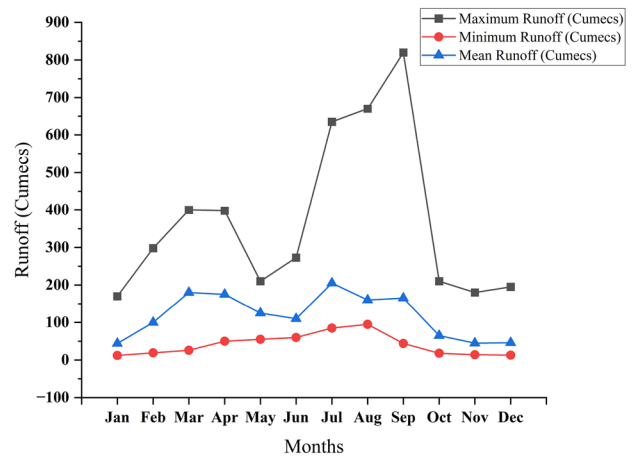


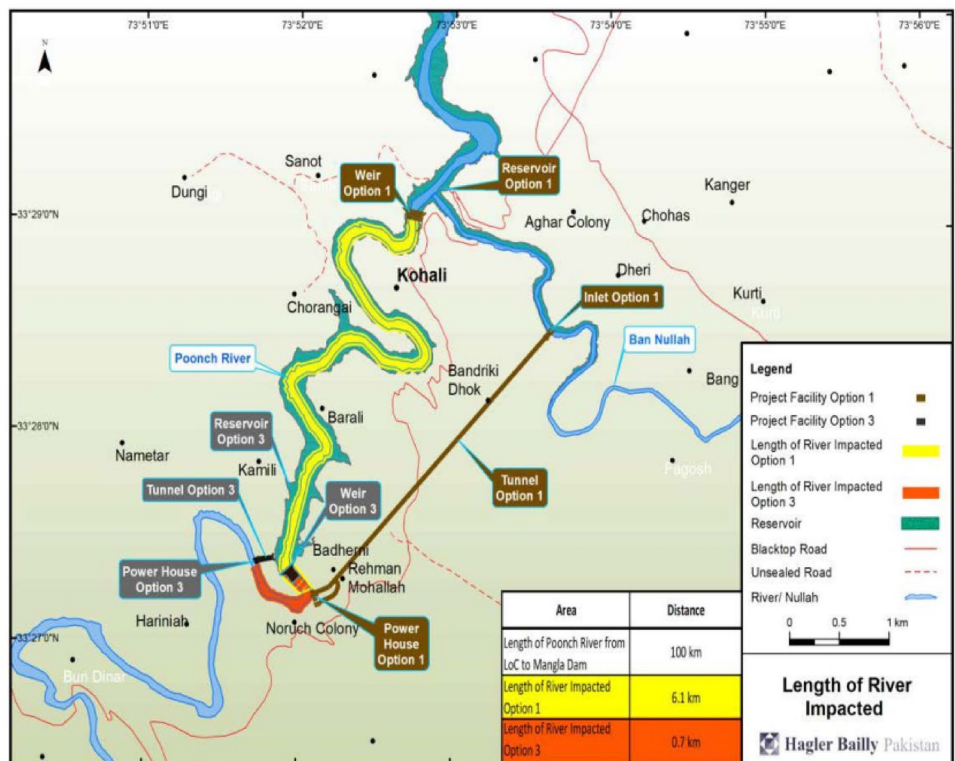
Fig. 6 Mean, max and min monthly runoff of Poonch river



has warm water, with summertime temperatures approaching thirty degrees Celsius. 37 Fish species from the Poonch River have been identified. Where the Poonch river meets the Mangla reservoir is where there is more diversity (richness). Compared to the larger and longer rivers in AJK, the Neelum, and Jhelum, this river’s diversity is rather remarkable for its size. The Poonch river’s terrain and water temperature are the cause. The Poonch river flows in a valley with plenty of fish breeding sites, where it flows quite slowly. Due to its location within Poonch river Mahaseer National Park and the presence of two fish species that are important for conservation, the Kashmir Catfish, *Glyptothorax kashmirensis*, and the Mahaseer *Tor putitora*—both of which are listed as Endangered and critically endangered on the IUCN red list, a critical habitat designation has been given to the project site. In order to fulfill the demands of the IFC’s performance standard 6 and the ADB’s SPS safeguards requirement (SR) 1, Mira Power Ltd has committed to achieving net gain for biodiversity within the Poonch river basin.

Figure 7 specifies the primary design distinctions among option 1 and 3. Option 2 was a layout that was positioned at an intermediate level in terms of both the dam’s placement and the tunnel. Upon comparison with the other two alternatives, it was determined that this option was not technically viable and did not provide any notable socioeconomic

Fig. 7 Options during ESIA for Gulpur hydropower project



benefits in comparison to option 1. As a result, it was eliminated from consideration early in the analysis. Figure 7 clearly demonstrates that Option 3 leads to a significantly reduced length of affected river.

4 Results

4.1 Survey results

Surveys at the settlement and household levels were carried out in February 2014. Male community members who either had significant leadership roles or, because of their age or line of employment, had firsthand knowledge of the colony were the main responders. 75% of those surveyed said that the Poonch River's changing flow would not significantly affect their recreational activities, while 23% said that the decrease in flow would negatively affect their ability to engage in recreational activities, particularly swimming and bathing. 40% of those surveyed stated that their reliance on the river ranges from 0 to 25% and is primarily restricted to livestock and recreational uses. In terms of livestock and leisure, 8% of respondents said they relied on rivers more than 75% of the time. Respondents in the rural area were asked whether a decrease in river flow any effect on them would have, based on data from a field survey. In response, 75% of respondents stated there wouldn't be any noticeable effects, while 23% claimed the decline in flow would have an adverse effect. Figure 8 shows the summary of responses on the effect of change in Poonch river flow on Recreation.

4.2 Environmental flow assessment

Hagler Bailly Pakistan appointed Southern waters for the evaluation of environmental flow (EFlow). The purpose of the EFlow assessment was to assess the Poonch river's current state, including its structure and functionality, upstream of the Gulpur HPP to the Mangla dam. It also aimed to assess potential changes in the river's state under various operational scenarios for the proposed Gulpur HPP. With agriculture fields making almost 35% of the habitat in the ecological study area (Fig. 9), they are the most prevalent type of habitat. Most of the agricultural land is located on the plains. During the October 2013 survey, the habitat's vegetation cover ranged from 0.5 to 16.5%, with an average of 33 plants. At each sampling site, there are three species of flowers in this ecosystem. In this ecosystem, the most common plant species are *Malvastrum coromandelianum*, *Dalbergia sissoo*, *Parthenium hysterophorus*, and *Broussonetia papyrifera*.

4.3 Potential impacts

The focus of the Gulpur HPP assessment were three EFlow sites on the Poonch river including one on the upstream of the hydropower project, one in the low flow region downstream of the intake, and one below the tailrace. The locations were chosen through a process of catchment delineation, which considered various factors such as river reaches with varying geomorphology, biological fluctuations throughout the river's length, diverse social applications, potential impacts of varying degrees resulting from project operations, and the safety and accessibility of site surveys. There will be an immediate and direct alteration of the land because of site clearance, project infrastructure construction, and the area submerged as a result of the reservoir's creation. This will result in a loss of terrestrial habitat (Area of Habitat Loss), which will cause a loss of animals and plants in this area. The estimated 313 hectares of the area affected by habitat loss are primarily made up of scrub forest and riparian habitat. This area of habitat loss has no known threats to any species

Fig. 8 Summary of responses on effect of change in Poonch river flow on recreation

Responses on effect of change in Poonch river's flow on recreation

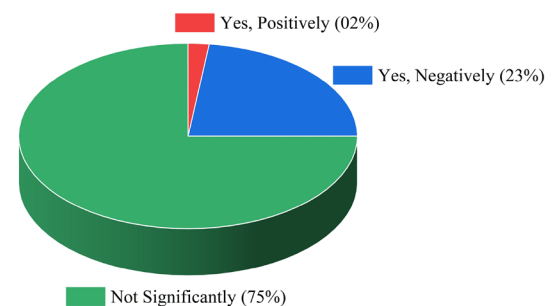


Fig. 9 Ecological study area: Gulpur hydropower project [38]



of plants or animals. The vegetation and animals surrounding the project facilities will be disturbed during the infrastructure construction process by noise, air pollution, blasting, vibrations, lighting, and dust. Table 2 shows the potential physical impacts of the Gulpur HPP.

4.4 Mitigation measures

For PE1, fuel tanks shall be properly labeled according to their contents and kept in covered spaces that hold an additional 10% of the fuel tank's storage capacity. An impermeable base will be used to border the space. Where necessary, grease traps will be placed on the site to stop the flow of oily water. Near fuel and oil storage locations, a spill cleaning kit consisting of shovels, plastic bags, and absorbent materials will be accessible. A developed emergency spill management plan will be given to the staff along with training in case of a spill.

For PE2, the removal of vegetation will be restricted to the clearly marked construction site. Following closure, areas including labor camps, muck disposal areas, batching plants, and quarry sites must be covered with grass and

Table 2 The potential physical impacts of the Gulpur hydropower project

Impact PE 1	The unintentional release of solvents, oils, and lubricants has the potential to cause soil contamination, leading to the degradation of surface and groundwater quality. Soil contamination can diminish soil fertility, hence decreasing its appropriateness for agricultural activities
Impact PE 2	The implementation of tunnel boring, land clearing, excavation, and other kinds of construction operations within the Project area has the potential to disrupt the stability of the top layer of soil. This can lead to soil loss and could increase the occurrence of soil erosion and land sliding, particularly during the wet season
Impact PE 3	The camp's construction and operation result in soil and water contamination by the release of many forms of waste, including solid waste, wastewater, and other types of solid and liquid waste
Impact PE 4	Utilizing regional water resources during construction activities may diminish the water supply accessible to the local communities
Impact PE 5	The activities of excavation, material storage, transporting materials, batching, along with vehicular movement will generate fugitive dust emissions, particularly during off-road driving
Impact PE 6	The emissions released by construction equipment, project traffic, including concrete batching machines can cause a decline in the air quality in the surrounding area
Impact PE 7	The presence of blasting, drilling, excavation work, batching plants, and generators in the area of the Project facilities may result in a disturbance due to the noise produced
Impact PE 8	The adverse effects of traffic congestion include decreased road safety and increased levels of noise, dust, and other pollutants

shrubs. Slope stabilization techniques will be used including cross drainage, retaining walls, and enough horizontal and vertical drains as well as roadside drainage. Slope movements around the excavation activity zones will be kept in mind.

For PE3, a wastewater treatment system will be built to guarantee that effluents meet lender requirements as well as NEQS standards during building and operation. It will not be permitted to discharge camp waste directly into waterways or onto land. During construction and business operations, the contractor will gather and remove waste from the site at a specified disposal spot. To stop seepage, cement lining of all effluent channels at all operating sites would be carried out. Should groundwater be discharged during digging, it will first undergo testing to determine its pH and sediment content. It will then be treated in sediment ponds to achieve acceptable levels of these parameters before being released into the Poonch river.

For PE4, water will be obtained from the river and a source authorized by the local government through a water contractor for use in various building operations. The EPC contractor will create and implement water-saving strategies. In order to ensure that the community can meet its water needs, access to water sources must be maintained unobstructed.

For PE5: To reduce fugitive dust, water will be sprayed on unpaved project roads during dry weather. The suspension of grading operations occurs when the wind speed surpasses 20 km/h. All fine-material storage heaps must be sufficiently moistened or covered with plastic to protect surrounding air from fugitive emissions during windstorms. Appropriate dust control solutions will be fitted with batching plants and related machinery. There will be strong enforcement of speed restrictions and defensive driving guidelines. Any damage to the road resulting from Project activities will be quickly repaired and maintained.

For PE6, low-emission vehicles and equipment in good operating order will be utilized. When the equipment is mobilized and on a regular basis thereafter, a visual inspection will be carried out to filter out vehicles and equipment that release excessive amounts of smoke. The equipment of the batching plant will be maintained, and exhaust emissions will be kept to a minimum. In order to prevent emissions from the batching plant from affecting the surrounding communities, the plant will be positioned with consideration for the direction of the wind. There will be routine servicing and maintenance performed on the equipment and vehicles.

For PE7: Construction machinery with the capacity to produce loud noises will be equipped with a suitable muffler system. Every stationary piece of noise-producing machinery, like power generators and air compressors, will be positioned at least 200 m away from any residential areas. If threshold values are surpassed, equipment distances should be adjusted based on the monitoring report. For project vehicles and equipment, a preventative maintenance protocol will be established and adhered to, helping to keep noise levels from declining over time. Personnel will be less affected by noise if Personal Protective Equipment (PPEs) such as earmuffs and plugs are available. Limitation on the pressurized horn. The locals will only be warned by sirens before blasting occurs, and it will only happen during the day.

For PE8, the contractor's vehicle will abide by all applicable local traffic laws and speed limits within the city, as well as those set forth by the National Highway Authority (NHA), particularly when it comes to sensitive receptors like schools, hospitals, mosques, and the like. A horn will never be used near sensitive sensors during the day. Discipline will be applied for exceeding the speed limit. Local commuters, ambulances, the army, and special person conveyances will always be given preference over other traffic, and drivers will be urged to yield. Employees of the contractor will only use the access routes allotted to them for project activities, which will be decided upon during a meeting with MPL and subcontractor representatives. Vehicles and trucks shall adhere to NHA regulations regarding load sizes and will not be overloaded. Large trucks that have the potential to severely slow down local traffic will only operate at night or with special permission granted by the district administration. Vehicles and equipment belonging to the contractor will be parked in the authorized area. The proper parking and placement of vehicles and machinery will be implemented to prevent any disruption to nearby commuters and pedestrians. Safety signs will be erected, and residents will be notified in advance of any activities taking place on the property. After the material is delivered to the Project site, the cars will be urged to get out of the neighborhood as soon as feasible. Only authorized workshops will be used for vehicle repair.

Increased intrusion into pristine areas, as well as a rise in the frequency of hunting activities and the trade in wildlife, may result from the influx of project workers and contractors throughout the construction and operations phase of the project. Regulations aimed at preventing illicit poaching by project personnel and contractors are among the mitigation strategies. Another is educating workers about pertinent legislation from the government. The hydropower plant's operations could cause some possible disturbances to certain species, which could worsen the impacts of habitat loss and dwindling species diversity. These disruptions consist of light and noise. Nonetheless, the impact of this is deemed to be limited given that no endangered species or habitat has been documented from the Zone of Impact. Implementing the Biodiversity Action Plan is one of the mitigation strategies used to protect the Poonch River Basin's ecological integrity.

5 Discussion

Poonch River flows vary from 279 m³/s in August to 41 m³/s in November on average [41]. The two Kaplan-type turbine units in the run-of-the-river Gulpur HPP have an average energy production of 436 Gwh. It is designed to produce 130,000 horsepower or 100 MW. The project might generate 465 GWh of energy on average every year. 75% of respondents to the survey stated that their recreational activities would not be significantly impacted by the Poonch River's changing flow, while 23% stated that their ability to participate in recreational activities particularly swimming and bathing—would be negatively impacted by the river's decreasing flow. Riparian habitat and scrub forests make up the majority of the 313 hectares of the area estimated to be affected by habitat loss. There are no known threats to any plant or animal species in this area of habitat loss. Blasting, noise, vibrations, lighting, air pollution, and dust will all cause disturbances to the surrounding vegetation and animals of the Project facilities during the infrastructure construction process. Possible effects were discussed, and workable mitigation strategies were found. Projects involving hydropower in delicate areas carry a high risk. In this instance, the risks have been thoroughly examined, and it is evident that the ESIA significantly impacted the project's design. The decision-makers initially preferred Option 1, but Option 3 has less impact on the environment and society. The alternative that was the primary subject of the ESIA was option 3 [42]. There will be a net environmental gain from the project if the environmental management controls specified in the ESIA are incorporated into its design. Because the project is slated to be implemented in a crucial habitat area, the Asian Development Bank and IFC have mandated this. For comparison, the study also had overview of the EIA procedure and mitigation measures along with the implementation at Karora hydropower project [43]. The study assessed at the region of influence, the land resources, the water resources, the flora and fauna, the socio-economic structure of the Shangla District, and consultations with the stakeholders, paying particular attention to any potential effects and concerns mentioned by the stakeholders and their compensations in accordance with the law [44]. The project has not had a negative influence on the environment, and the potential damages and compensation were handled efficiently and in accordance with the law at Karora hydropower project too.

In addition, recent published studies have illustrated importance of environmental management and associated regional aspect considering climate parameters, hydropower project delineation and regional hydrological attributes in some of northwest India, where they have reported climate parameters and anthropogenic activities are collectively liable for environmental dilapidations, which needs to be incorporated in development and long-term sustainability of HPP [19, 25]. After thorough literature, it was observed that the EIA guidelines implemented in Pakistan promote sustainable economic development in conjunction with hydropower projects, as economic sustainability aims to enhance living standards. Conversely, social sustainability focuses on improving social equity [45]. The EIA process in Pakistan takes into account the measures necessary to safeguard the local communities, ecosystems, and cultural heritage during the implementation of the project. This indicates that the current EIA guidelines in Pakistan include measures to address and minimize potential environmental effects.

6 Conclusions

With funding from the Asian Development Bank (ADB), AJK government, and Mira Power Limited (MPL) supervised the Gulpur HPP. Hagler Bailly (Pakistan) was also involved in the EIA procedures. In addition to making further observations and reviewing the literature, the study looked at Mira Power Limited's EIA reports. The possible effects as well as the government's and MPL's mitigating actions were examined by the writers. EIA procedures at the Gulpur HPP considered the Pakistan Environmental Protection Agency; the AJK Wildlife Ordinance of 2013; the Strategies for Public Consultation, Pakistan EPA; the Land Acquisition Act, 1894; the Jammu and Kashmir Forest Regulations of 1930; the Fisheries Act, 1897; the Factories Act, 1934; the Explosives Act, 1884; and Laws Regulating Flow Releases for Hydropower Projects. The region of influence, the land and water resources, the flora and fauna, the socioeconomic structure of the Kotli district, and the stakeholder consultations were all examined by the authors. The study found that the assessment of Flora and Fauna was taken into account when applying the Environmental Impact Assessment (EIA) guidelines to the Gulpur hydropower project in Pakistan. The statement emphasizes the adherence to the EIA Guidelines in Pakistan for determining the worth of ecological resources, describing the effects of proposed development, evaluating the importance of those effects, and assessing any remaining consequences. Special attention

was given to any potential effects and concerns raised by the stakeholders, as well as their legal compensations. The authors concluded that there has been no adverse impact on the environment from the project and that the handling of potential impacts and compensation was done effectively and legally. The research recommends that an environmental impact assessment should be done for all hydropower projects in Pakistan. Developed countries frequently update their EIA guidelines to effectively address emerging challenges. Upon reviewing the literature, it was noted that in Pakistan, there is a need for a well-established system to embrace changes and ensure that guidelines are regularly updated in accordance with the passage of time. An exhaustive examination of the EIA system reveals various aspects that can be further enhanced, encompassing the organizational structure, execution, and tangible procedures. Furthermore, it is imperative that the EIA guidelines are harmonized with the internationally recognized guidelines implemented in developed nations. Additionally, decision-makers must undergo thorough training and possess up-to-date knowledge in order to effectively adapt to the progress of the present era.

The study just focused on the EIA implementation process for the Gulpur HPP and was based on the survey results and documentation assessment by Mira Power Limited and Asian Development Bank. Moreover, another significant constraint of this study was to demonstrate concise implementations of EIA and re-allocation programs before and after the structural measurement of concerned hydropower project.

Acknowledgements The authors would like to thank every person who has collaborated for this study, especially Mira Power Limited working at Gulpur HPP for providing the relevant material and information with official documents to complete the study. The completion of this study could not have been possible without their cooperation.

Author contributions AQB: Conceptualization, methodology, visualization, formal analysis, writing—original draft, writing—reviewing and editing, DS: supervision, project administration, funding acquisition, writing—reviewing and editing, YD: conceptualization, supervision, writing—reviewing and editing, AB: investigation, writing—reviewing and editing, MAM: writing—reviewing and editing, KT: formal analysis, writing—reviewing and editing.

Funding The international partnership of Chinese Academy of Sciences (Grant No. 131C11KYSB20200022), the Ministry of Science and Technology (Grant No. 2018FY100502), and the Gansu Provincial Science and Technology Program (Grant No. 22ZD6FA005) provided financial support for this study, which the authors gratefully acknowledge.

Data availability The data/ material used to sort out the findings of this research are accessible upon request from the corresponding author.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

1. Butt AQ, et al. Ascertainment of hydropower potential sites using location search algorithm in Hunza river basin, Pakistan. *Water*. 2023;15(2929):1–19.
2. Ullah S, Sherin S, Khan J, Fahad M. Deterministic seismic hazard assessment of Karora Hydro power plant. *Int J Adv Eng Res*. 2020; 2019.
3. McManamay RA, Parish ES, DeRolph CR, Witt AM, Graf WL, Burtner A. Evidence-based indicator approach to guide preliminary environmental impact assessments of hydropower development. *J Environ Manage*. 2020;265:110489.
4. Butt FK, et al. An experimental study to mitigate environmental impacts by transforming waste plastic bags into paving blocks and roof tiles. *Sustainability*. 2023;15(22):15801.
5. Pathak S, Sharma S, Banerjee A, Kumar S. A methodology to assess and evaluate sites with high potential for stormwater harvesting in Dehradun, India. *Big Data Res*. 2023;35:100415.

6. Lata R, Rishi S, Rk H. Environmental implications of the hydropower projects in district Kinnaur, Himachal Pradesh, India: a review. *Int J Earth Sci Eng*. 2017;7301:8–13.
7. Sinclair AJ, Diduck AP. Public involvement in environmental impact assessment: a case study of hydro development in kullu district, Himachal Pradesh, India. *Impact Assess Proj Apprais*. 2000;18(1):63–75.
8. Rajaram T, Das A. Need for participatory and sustainable principles in India's EIA system: lessons from the Sethusamudram Ship Channel Project. *Impact Assess Proj Apprais*. 2006;24(2):115–26.
9. Diduck A, Sinclair J, Pratap D, Hostetler G. Achieving meaningful public participation in the environmental assessment of hydro development: case studies from Chamoli district, Uttarakhand, India. *Impact Assess Proj Apprais*. 2007;25(3):219–31.
10. Paliwal R. EIA practice in India and its evaluation using SWOT analysis. *Environ Impact Assess Rev*. 2006;26(5):492–510.
11. Javeed B, Huang D, Shangguan D, Banerjee A, Yang Q, Butt AQ. Assessing the effectiveness of national park's policies and laws in promoting biodiversity conservation and ecological development in Pakistan. *Front Environ Sci*. 2024;11:1–13.
12. UN (United Nations - Environment), Assessing environmental impacts—a global review of legislation. United Nations Environment Programme, Nairobi, Kenya. 2018. <http://hdl.handle.net/20.500.11822/22691>.
13. Afzal M, Liu T, Butt AQ, Nadeem AA, Ali S, Pan X. Geospatial assessment of managed aquifer recharge potential sites in Punjab, Pakistan. *Remote Sens*. 2023;15(16):3988.
14. Solomon AA, Child M, Caldera U, Breyer C. How much energy storage is needed to incorporate very large intermittent renewables? *Energy Procedia*. 2017;135:283–93.
15. Hoes OAC, Meijer LJJ, Van Der Ent RJ, Van De Giesen NC. Systematic high-resolution assessment of global hydropower potential. *PLOS ONE*. 2017;12(2):1–10.
16. Ansar A, Flyvbjerg B, Budzier A, Lunn D. Should we build more large dams? The actual costs of hydropower megaproject development. *Energy Policy*. 2014;69(April):43–56.
17. Kibler KM, Tullos DD. Cumulative biophysical impact of small and large hydropower development in Nu River, China. *Water Resour Res*. 2013;49(6):3104–18.
18. Ahmad K, Banerjee A, Rashid W, Xia Z, Karim S, Asif M. Assessment of long-term rainfall variability and trends using observed and satellite data in central Punjab, Pakistan. *Atmosphere (Basel)*. 2022;14(1):60.
19. Banerjee A, et al. Tracking 21st century climate dynamics of the Third Pole: An analysis of topo-climate impacts on snow cover in the central Himalaya using Google Earth Engine. *Int J Appl Earth Obs Geoinf*. 2021;103:102490.
20. Butt AQ, et al. Gradual changes in snow peaks in upper Indus basin, Pakistan: a google earth based review. *J Mt Area Res*. 2023;7:37–43.
21. McDonald K, Bosshard P, Brewer N. Exporting dams: China's hydropower industry goes global. *J Environ Manage*. 2009;90(Suppl. 3):S294–302.
22. Zimny J, Michalak P, Bielik S, Szczotka K. Directions in development of hydropower in the world, in Europe and Poland in the period 1995–2011. *Renew Sustain Energy Rev*. 2013;21:117–30.
23. Zarfl C, Lumsdon AE, Berlekamp J, Tydecks L, Tockner K. A global boom in hydropower dam construction. *Aquat Sci*. 2015;77(1):161–70.
24. NIAP, EIA guidance for large-scale hydropower in Pakistan. Pakistan: National Impact Assessment Programme; 2014.
25. Banerjee A, Kang S, Meadows ME, Xia Z, Sengupta D, Kumar V. Quantifying climate variability and regional anthropogenic influence on vegetation dynamics in northwest India. *Environ Res*. 2023;234:116541.
26. Banerjee A, et al. Long-term climate change and anthropogenic activities together with regional water resources and agricultural productivity in Uganda using google earth engine. *Phys Chem Earth*. 2024;134:103545.
27. Lee N, Tomkins JM. The quality of environmental impact statements in Ireland and the United Kingdom: a comparative analysis. *Proj Apprais*. 1993;8(1):31–6.
28. Wende W. Evaluation of the effectiveness and quality of environmental impact assessment in the federal republic of Germany. *Impact Assess Proj Apprais*. 2002;20(2):93–9.
29. Tzoumis K, Finegold L. Looking at the quality of draft environmental impact statements over time in the United States: Have ratings improved? *Environ Impact Assess Rev*. 2000;20(5):557–78.
30. Erlewein A. Disappearing rivers—the limits of environmental assessment for hydropower in India. *Environ Impact Assess Rev*. 2013;43:135–43.
31. Botelho A, Ferreira P, Lima F, Pinto LMC, Sousa S. Assessment of the environmental impacts associated with hydropower. *Renew Sustain Energy Rev*. 2017;70:896–904.
32. Bakken TH, Sundt H, Ruud A, Harby A. Development of small versus large hydropower in Norway comparison of environmental impacts. *Energy Procedia*. 2012;20:185–99.
33. Zelenáková M, Fijko R, Diaconu DC, Remeňáková I. Environmental impact of small hydro power plant—a case study. *Environ MDPI*. 2018;5(1):1–10.
34. Pinho P, Maia R, Monterroso A. The quality of Portuguese environmental impact studies: the case of small hydropower projects. *Environ Impact Assess Rev*. 2007;27(3):189–205.
35. Jumani S, Rao S, Machado S, Prakash A. Big concerns with small projects: evaluating the socio-ecological impacts of small hydropower projects in India. *Ambio*. 2017;46(4):500–11.
36. Daini P. Environmental impact assessment for hydroelectric power plants in Trentino (Italy) 1990–1997: similarity and clustering of studies, sites and projects. *Impact Assess Proj Apprais*. 2000;18(1):43–60.
37. Souza-Cruz-Buenaga FVA, Espig SA, Castro TLC, Santos MA. Environmental impacts of a reduced flow stretch on hydropower plants. *Braz J Biol*. 2019;79(3):470–87.
38. Mira Power Limited, Environmental and social impact assessment: Gulpur hydropower project (Pakistan), 2014.
39. Wikipedia, Gulpur hydropower project. 2023. https://en.wikipedia.org/wiki/Gulpur_Hydropower_Project.
40. British International Investment, British international investment: Gulpur hydropower. 2018. <https://www.bii.co.uk/en/our-impact/investment/gulpur-hydropower/>.
41. Hasnat A. Gulpur hydropower plant project full report. 2019. <https://www.slideshare.net/HasnatAmin1/gulpur-hydropower-plant-project-full-report-2019>.

42. Dutch Sustainability Unit, Environmental and social impacts associated with the proposed Gulpur hydropower project, state of Azad Jammu & Kashmir. 2015.
43. PEDO, Karora hydropower project: Pakhtunkhwa energy development organization. 2016. <https://pedokp.gov.pk/Main/psp/37>.
44. GRC, Design, procurement and construction of Karora hydropower project (10.80 MW). 2016. <https://grc.com.pk/design-procurement-and-construction-of-karora-hydropower-project-10-80-mw/>.
45. Butt AQ, Shangguan D, Ding Y, Banerjee A, Sajjad W, Mukhtar MA. Assessing the existing guidelines of environmental impact assessment and mitigation measures for future hydropower projects in Pakistan. *Front Environ Sci.* 2024;11:1–17.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.