STRATEGY FOR SUSTAINABLE HYDROPOWER DEVELOPMENT IN THE JHELUM POONCH RIVER BASIN PAKISTAN

IN PARTNERSHIP WITH

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FOREWORD

IFC's renewable-energy investments and advisory services span the globe-from Africa, Asia, Eastern and Southern Europe to Latin America and the Middle East. Hydropower is IFC's largest investment in the renewable portfolio and also an area in which IFC has been providing advice since 1991.

Our Hydro Advisory Program advises environmental and energy regulators on hydropower policies and regulations, provides banks with diagnostic tools to lower risks when lending to hydropower companies, and helps developers assess and manage cumulative impacts from multiple projects in the same river basin, thus improving their performance and sustainability. Many hydropower projects would not reach fruition without IFC's interventions.

In Pakistan, IFC has been investing in the power sector since 1995 and has committed about $1.02 billion across 18 projects to help the country increase its generation capacity by over 6,100 megawatts. Our goal is to help around 12 million people gain access to electricity while promoting renewable-energy solutions and improving environmental and social standards in the country.

Our current investments include three operational hydropower projects-namely the New Bong Escape, Patrind, and Gulpur-as well as the Karot project that is near completion; two thermal-gas power projects; six wind projects; and a stake in China Three Gorges South Asia Limited (CSAIL), a platform company that is expected to develop six renewable-power (mostly hydro) projects with total installed capacity of over 2,600 megawatts. In addition, IFC has also financed the country's first liquefied natural gas import terminal developed by Engro Elengy Terminal (Private) Limited.

Traditionally, environmental and social risks of power projects are managed individually, but IFC takes a holistic approach in addressing the impacts of projects on the ecosystems and communities across an entire region. To ensure Pakistan's hydro resources are developed sustainably, IFC's Environmental, Social, and Governance Advisory Program advises companies on environmental and social risk management, paving the way for more private sector investments in the sector.

As part of its efforts, the program has developed a Strategy for Sustainable Hydropower Development in the Jhelum Poonch River Basin (JPRB). Designed in consultation with government officials, developers, investors, and representatives from environmental organizations and academia, this strategy is the first comprehensive basin-wide development road map built on the experiences of individual hydropower projects. It has incorporated a set of common guidelines for all hydropower plants operating in the region, including a coordinated plan to manage water flows and sediment flushing along the rivers. This innovative approach represents a win-win for the government and hydropower companies in tapping Pakistan's natural resources for energy production while maintaining its environment and biodiversity. It can serve as an example of good practice to be followed in other basins within and beyond the country.

Nadeem A. Siddiqui
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MESSAGE

Although Pakistan is rich in natural resources, the country still depends heavily on fuel import for power generation. The current mix of around 70 percent non renewables comes mainly from gas, furnace oil, and coal. These imported thermal sources not only produce more and more greenhouse-gas emissions in the country but also pose a heavy burden on the economy and substantial risks to investments.

With its immense renewable-energy potential, growing economy, and an established regulatory framework, Pakistan can be the perfect market for investments in renewable-energy projects, including hydropower, wind, and solar. Such investments also make economic sense as the prices of renewable-energy sources have continued to drop globally: renewables are already the cheapest form of new electricity generation in Pakistan. Despite higher construction costs, hydropower provides the most cost-efficient electricity over the long run. Pakistan has barely tapped into its tremendous potential; Only 10100 megawatts of hydropower projects has been commissioned as of 2020. More projects are in the pipeline.

Common challenges confronting hydropower development include high construction costs, long construction periods, and negative environmental and social impacts. These challenges, if not managed well, pose risks of project delays that will further drive up costs. It is therefore important for hydropower developers and government departments to anticipate such challenges and implement good practice in their development and operations to address unforeseen risks.

IFC has remained financer and development partner in hydropower projects in Pakistan. In this process, IFC has developed a comprehensive approach for developing sustainable hydropower as a cheaper and cleaner energy that benefits the environment as well as the communities in the area. A key part of the approach involves raising environmental and social standards in hydropower development through its advisory engagements. Strategy for Sustainable Hydropower Development in the Jhelum Poonch River Basin (JPRB) is one such IFC initiative implemented through a multistakeholder-engagement process to provide practical guidance for government, developers, and other stakeholders.

The proposed strategy presents key lessons learned from hydropower projects in the Jhelum-Poonch River Basin as well as other related basins during construction and operation. It enhances the knowledge base of the Jhelum-Poonch Basin and provides recommendations for hydropower developers and government to implement best practice in their projects. This helps strike a balance between conservation and development by minimizing negative environmental and social impacts from hydropower projects in the basin.

The strategy provides recommendations for government and regulators on how to improve policy and regulation to strengthen the hydropower sector. Developers can make good use of this report to strengthen their planning, systems, and business operations. We look forward to working with all stakeholders in pursuing a sustainable hydropower development approach to manage environmental and social risks while maximizing energy generation for our country's consumption and economic growth.

Shah Jahan Mirza
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and Chief Executive Officer of the Alternative Energy Development Board (AEDB),
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ACKNOWLEDGMENTS

The sustainable hydropower development strategy described in this report outlines a framework for minimizing the negative environmental and social impacts of hydropower projects in the Jhelum-Poonch Basin. IFC led the project with support from relevant stakeholders, particularly government departments, non-governmental organizations, and hydropower developers.

IFC's Hydro Environmental and Social Advisory (www.ifc.org/hydroadvisory) team who spearheaded this endeavor includes Kate Lazarus, Leeanne Alonso, Pablo Cardinale, Jahanzeb Murad and Mir Ali Hamza. They provided direction and guidance to the process and ensured this report meet the quality standards of IFC and the World Bank Group.

Special thanks to our consultant, Hagler Bailly Pakistan, for developing the report. Team members included Vaqar Zakaria, Fareeha Irfan Ovais, Muhammad Rafique, Ahmed Shoaib, Anwar Fazal, Cate Brown, and the late Bilal Khan.

This report would not have been possible without the inputs of the forestry, wildlife, and fisheries departments and the environmental protection agencies of the Azad Jammu and Kashmir, Khyber Pakhtunkhwa, and Punjab governments. In addition, the Pakistan government's Private Power and Infrastructure Board and the National Electric Power Regulatory Authority gave feedback at several rounds of meetings and workshops. Also vital to the development of the strategy was comments and feedback from civil society, particularly the Himalayan Wildlife Foundation.

We are thankful for the generous support of Australia's Sustainable Development Investment Portfolio and the Korea-IFC Partnership Program.

Finally, we would like to thank members of the Hydropower Developers' Working Group who participated in the process and provided inputs for this report. They include Mira Power Ltd., Kohala Hydropower Co. Ltd., Karot Power Co. Ltd., Mahl Power Co. Ltd., Azad Pattan Power Private Ltd., Laraib Energy Limited, and Star Hydro Power Limited.

EXECUTIVE SUMMARY

Introduction

The Jhelum-Poonch Basin is an important strategic basin for Pakistan. It holds enormous potential for hydropower generation—a necessity for a developing country like Pakistan recently recovered from a severe energy deficit. However, the rivers of this basin are also important for supporting aquatic biodiversity and a range of ecosystem services for the local communities. They provide habitats to many fish species, including several of conservation importance—the Endangered Golden mahseer, the Critically Endangered Kashmir catfish, and the long-distance migratory Alwan snow trout. The strategy for sustainable hydropower development, described in this document, aims to balance conservation and development as well as minimize the negative environmental and social impacts of hydropower projects in the basin. This strategy has been prepared by IFC with support from all relevant stakeholders, including government departments, non-governmental organizations (NGOs), hydropower developers, and researchers.

Figure ES1 illustrates the Jhelum-Poonch Basin, which is defined as the catchment draining into the Mangla Reservoir up to the Mangla Dam. The basin, consisting of the Upper Jhelum River and its tributaries, is divided into six subbasins.

For this study, the area of management includes the subbasins of the Jhelum-Poonch Basin falling within Pakistan's territory. Administratively, the area of management includes the state of Azad Jammu and Kashmir (AJK), three districts of Khyber Pakhtunkhwa (KP), and one district of Punjab. The Indian-administered Kashmir across the Line of Control has been excluded from the area of management.

Figure ES2 shows the hydropower projects (HPP) in the Jhelum-Poonch Basin. There are 22 HPPs in Pakistan and India; the area of management in Pakistan currently has three HPPs in operation, two under construction, five committed, and seven planned.

Figure ES1: Subbasins in the Jhelum-Poonch Basin

Figure ES2: Hydropower Projects in the Jhelum-Poonch Basin

Objectives of the Strategy

The objective of the strategy for sustainable hydropower development in the Jhelum-Poonch Basin is to enhance the knowledge base of the basin, evaluate information, and provide recommendations for hydropower developers and government departments to implement good practice in their operations. In addition, the strategy aims to share and engage with all stakeholders for good practices towards a balance of development and ecosystem conservation.

The studies included in the development of this strategy aim to:

- Provide an overview of the baseline conditions in the area of management, including physical conditions, aquatic and terrestrial ecological resources, and socio-economic profile.
- Promote the sustainable and wise use of natural resources with respect to hydropower development.
- Provide good practice measures for existing and potential developers to strategically manage the negative impacts of hydropower development.
- Provide recommendations for government departments to minimize risks and manage negative impacts of hydropower development.
- Outline lessons learned for protecting the environment, preserving ecological resources, and managing stakeholder concerns during the planning, construction, and operation of hydropower projects.
- Enhance the benefits of hydropower projects for communities and ecosystems through participatory planning and capacity building.

The key basin-wide studies conducted to inform the strategy (attached in their entirety in the Annexes) include the following:

- Summary of physical conditions of the basin
- Sediment audit
- Zones of ecological importance
- Zones of socio-economic importance
- Impacts of HPPs on sediment, geomorphology, socio-economics, and other HPPs
- Assessment of cumulative HPP impacts on the ecology of the basin (DRIFT modelling)

Success of this strategy depends on a collaborative approach among hydropower developers, government, civil society, lenders, and local stakeholders.

Summary of Physical Conditions in the Basin

Topography

The Jhelum River catchment up to the Mangla dam is at the western edge of the Higher Himalayan range. Based on the topography, the catchment area can be subdivided into four units: alpine area at the north (3,500 m); medium- and high-mountain area in the northern and central part of this region (2,000 m); low-to-medium-mountain area in the central part of this region (500–2,500 m), and the plain area toward the south of this region (200 m).

Earthquakes and Land Stability

The basin's area of management is on the Himalayan thrust nappe. Most of the strata in the north of the area is made up of Precambrian metamorphic igneous sedimentary rocks, while the southern part of the area is dominated by Tertiary sedimentary rocks. The area is in a seismically active zone affected by the continuing northward drifting of the Indian plate and its subduction below the Eurasian plate. Several regional and local faults are active in the area, with heavy rainfall and associated flooding increasing the risk of landslides, particularly after the 2005 earthquake.

Seasons

Four seasons can be identified in the Jhelum-Poonch Basin: summer (mid-March to mid-June), summer monsoon (mid-June to mid-September), post-monsoon summer (mid-September to mid-November), and winter (mid-November to mid-March).

An evaluation of the mean monthly temperatures in the subbasins of the Jhelum-Poonch Basin shows that the Neelum Basin is the coldest basin, while the Poonch Basin and the Lower Jhelum Basin have comparatively higher mean monthly temperatures. The Jhelum-Poonch Basin lies at the edge of the core monsoon region of Pakistan and western Himalaya, experiencing the South Asian summer monsoon, also known as the Southwest monsoon.

Flow Rates

The mean monthly flows within the Upper Jhelum and its tributaries do not completely correspond to the precipitation, particularly for winter. This is because the catchment experiences snowfall, associated with the western disturbances in winter months, which does not immediately report to the river. In spring, as temperatures start to rise, snow melts and the flow increases, compounding the impact of rainfall during the South Asian summer monsoon.

There is a positive relationship between flow and summer precipitation (rainfall) as well as a negative relationship between flow and temperature.

Land Cover

Land-cover classes in the basin include forests and scrubs, grasses and sparse vegetation, orchards, cultivated cropland, urban areas, bare land, waterbodies, and snow and ice. Analysis of changes in land cover for this study showed that forests and scrubs were the most dominating feature in 1993, but bare land overtook them by 2014. Forests and scrubs decreased by 6.6 percent, while bare land increased by 8.6 percent during this period. In the area of management, forests and scrubs have decreased while barren land and urban area have increased. The areas of grasses and sparse vegetation have remained similar.

Sediment Audit

A sediment audit was conducted to evaluate the sediment profile of the rivers in the area of management. The audit assessed existing sediment data for the Jhelum rivers and basin geology information to predict how sediment loads and patterns are expected to change with hydropower development in the basin.

Key findings are outlined below:

- In their natural state, the main rivers in the Jhelum Basins have sufficient energy to transport the material being shed by the rapidly uplifting mountainous terrain, which has resulted in deeply incised and steep valleys with limited accumulation of alluvial deposits.
- The Neelum River is the largest source of sediment in the Neelum-Jhelum Basin, contributing almost half of the sediment to the lower Jhelum River and more than a third of the sediment reporting to the Mangla Reservoir. The remaining sediment in the lower Jhelum River comes from the middle Jhelum and Kunhar rivers and the area draining to the Mahl and Azad Pattan HPP sites. The Poonch River contributes about 24 percent of the load entering the Mangla Reservoir.
- There is a poor correlation between river flow and sediment transport, which is governed more by the delivery of sediment to the rivers than by their transport capacities. Sediment inputs can vary markedly over short distances.
- May and June tend to have peak sediment transport because they coincide with a period of high erodibility of the mountain slopes.

Ecological Importance of Zones in Area of management

The basin has four important and distinct rivers: the Neelum, the Kunhar, the Jhelum, and the Poonch. These rivers are divided into 10 different zones from A to J based on ecological similarities (**Figure ES3**).

These river zones vary in their sensitivity to hydropower development. The ecological importance of each zone was assessed using four indicators: fish diversity, conservation status of species, status as protected area, and the economic value of fish.

Based on these indicators, the sensitivity of each ecological zone to the construction and operation of HPPs was categorized as "highly sensitive," "moderately sensitive," and "least sensitive."

Two designated river zones—Zone I (Mahl River) and Zone J (Poonch River and tributaries)—are classified as "highly sensitive" because of their fish diversity and the presence of fish of high conservation importance in existing or proposed protected areas. Only Zone D (Neelum River from Dudhnial to Muzaffarabad) has been categorized as "least sensitive" to hydropower development because of its low ecological importance.

All other zones have been classified as "moderately sensitive." The sensitivity zones are shown in **Figure ES3**.

Overview of Socio-economic Conditions

The socio-economic zones in the area of management are the same as those selected for ecology. Each zone's socio-economic importance and sensitivity to hydropower development was calculated using three indicators: fishing, sand and gravel mining, and tourism potential. Based on these indicators, the sensitivity of each zone to the construction and operation of HPPs has been placed in three categories: "highly sensitive," "moderately sensitive," and "least sensitive." **Figure ES4** shows the distribution of the zones.

Zone J (Poonch River) was categorized as "highly sensitive" to the construction and operation of hydropower projects. This is because fishing has high commercial, subsistence, and recreational importance in this zone, while sand and gravel mining is extensive and meets the requirements of a large population;

Figure ES3: Ecological Sensitivity Zones for Hydropower Development

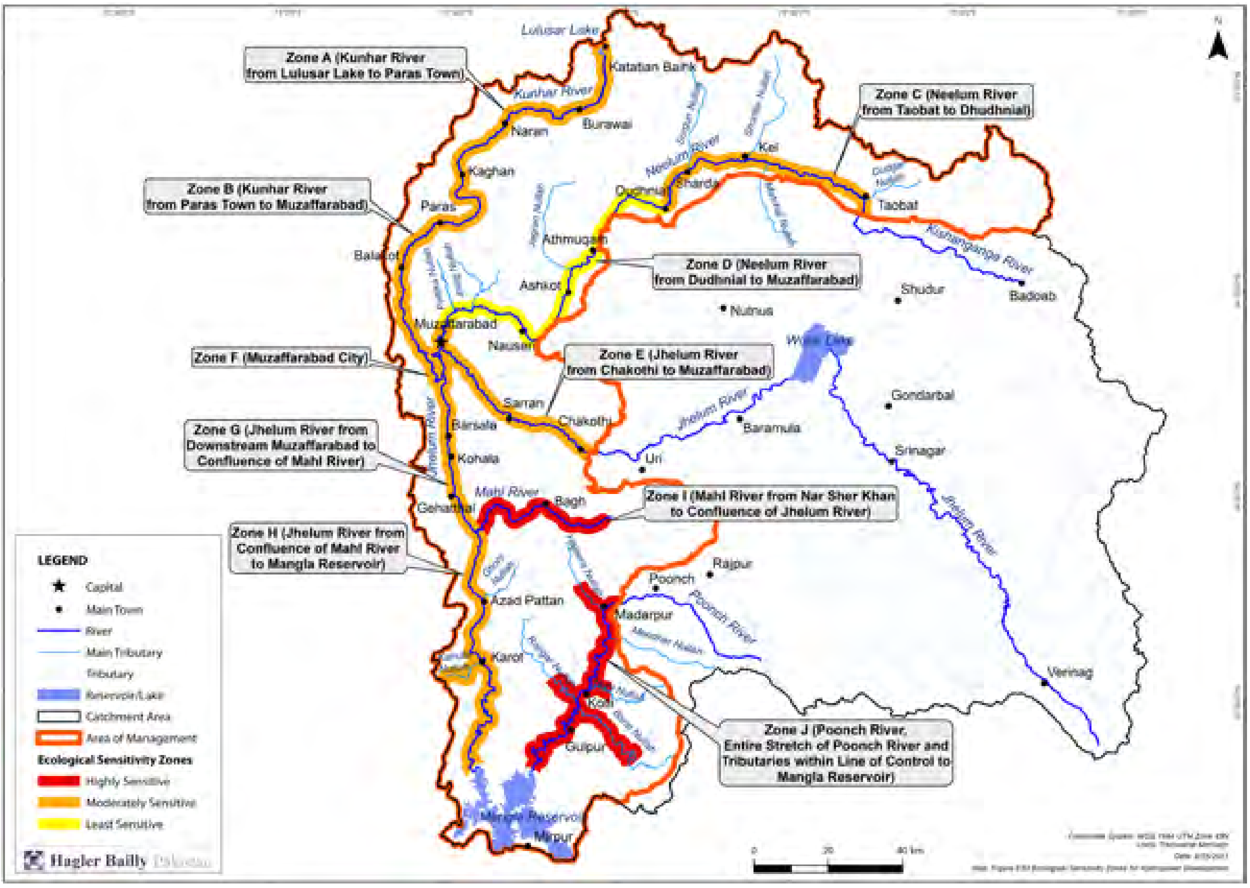
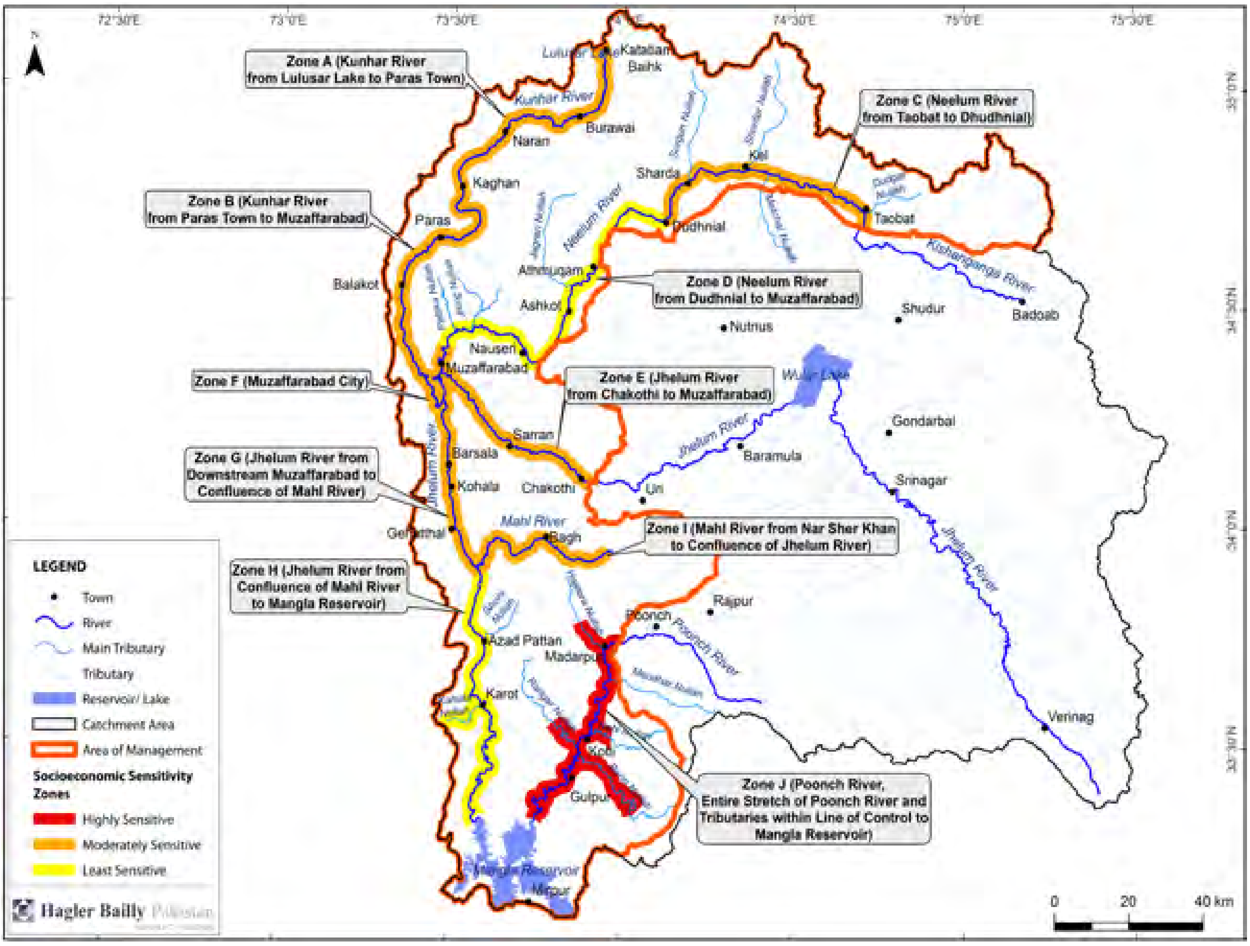


Figure ES4: Socio-economic Sensitivity Zones for Hydropower Development



moreover, it has tourism potential in the winter. Two zones were categorized as "least sensitive" to hydropower development impacts. They are Zone D, which covers the area around the Jhelum River from Dudhnial to Muzaffarabad, and Zone H, which covers the area around the Jhelum River from the confluence of the Mahl River to the Mangla Reservoir. People living in these zones have little dependence on commercial fishing, sediment mining, and tourism. All other zones have been categorized as "moderately sensitive" to hydropower development.

Impacts on Sediment, Geomorphology, Socio-economics, and Other HPPs

Impacts on Sediment Transport

Each hydropower project in the Jhelum and Poonch catchments will affect the sediment movement locally and further downstream. In the Jhelum, where there are numerous intrabasin transfers, changes in sediment loads will affect both the donor and recipient catchment. In summary,

- Smaller pulses of sand and silt captured in sediment traps upstream of powerhouses will be episodically flushed to the downstream river.
- The diversions will direct equivalent proportions of silt and clay as water, and less portions of sand, from one river to another.
- The hydraulics of river channels will change. Rivers with water diverted will have reduced energy, while those receiving the water will experience increased flow and energy.

All hydropower projects will trap virtually all gravel entering the impoundment. Some projects have very low-level outlets specifically to reduce the amount of time until coarse material can be flushed downstream, but other projects will promote deposition until the sediment deposits reach the level of the sluice gates. Time frames required to achieve equilibrium are difficult to identify and vary owing to the morphology of impoundments and rate of sediment input.

The annual flushing of sediment can affect the downstream river system and HPPs, especially in the Lower Jhelum cascade where sediment flushed from one impoundment will directly enter the next impoundment downstream. The nature and extent of impacts will vary with distance from the dam, the flow pattern during flushing, and the volume and duration of flow following the release of the large sediment load.

Geomorphic Impacts

The river channel immediately downstream of a dam has a high risk of scour, as water discharged from the dam erodes the river, but no subsequent sediment deposition occurs. Water diversions will reduce the river's sediment transport capacity for many kilometers downstream of the diversion site for most of the year. This means the river may transport less grain-sized sediment and increase sedimentation. Lower river levels can encroach on vegetation, while the flushing of accumulated sand in the impoundments downstream of diversion projects into the original river channel can reduce its capacity. There is also a risk that flushed material deposited on riverbanks will become cemented and affect riparian habitats and fish breeding grounds. Tributaries downstream of HPPs diverting water out of the catchment will be discharging into lower base levels. This will increase the water surface slope, river energy, and also erosion in the lower channel of the tributary.

Socio-economic Impacts

Bedload will be trapped in the reservoirs of the hydropower projects, while suspended sediment and sand fractions will be released when the reservoirs are flushed. The number of years that the sediments will accumulate in the reservoirs will vary but in the order of five to 15 years, depending on the reservoir size, sediment inflow, and flushing design. As the cascade of hydropower projects comes in place, the expected outcomes are discussed below.

Boulders, cobbles, and gravel (bedload) for mining will be available only in the river segments upstream of the dams that are first in the catchments. This means the Suki Kinari HPP in the Kunhar River, the Athmuqam or Dudhnial HPP in the Neelum River, the Kohala HPP in the Jhelum River, and the Gulpur HPP in the Poonch River.

Availability of sand will be restricted initially when the reservoirs reach an equilibrium. Some sand will be available as sediments are released from the sand traps installed at the dams to reduce flow of sediments into the powerhouse turbines. After the reservoirs have reached an equilibrium, coarser sand fractions will be flushed out typically once a year, while sand will not be available downstream of the dams for the rest of the year. Sand will be available for communities to mine; however, the location of sand deposits will shift as the dams are constructed and operated.

Impacts on other HPPs

Sediment flushing will affect downstream rivers and HPPs. For example, the lower Jhelum River will experience large inflows of water and sediment whenever the Neelum-Jhelum, Kohala, or Patrind projects implement flushing. If the projects flush sediments simultaneously, huge sediment loads and floods may occur as the material arrives in the lower river. Flushing within the cascade—for example, from the Mahl HPP to the Azad Pattan HPP—will require a similar level of coordination.

Flushing at the end of the wet season has been proposed to increase capacity for water storage for peaking during the dry season. If sediment flushing coincides with high-flow events, sediment and water pulses, combined with "natural" inflows, may increase flooding, especially if the channel has been infilled by sediment from tributaries.

Assessment of Cumulative HPP Impacts on Basin Ecology

Impacts of HPPs on the aquatic ecological resources and ecosystem integrity in the Jhelum-Poonch Basin were assessed using the DRIFT (Downstream Response to Imposed Flow Transformations) Decision Support System (DSS), an internationally recognized environmental-flow (EFlow) assessment model for river systems. The DRIFT model (Jhelum DSS) was first configured by Southern Waters in collaboration with Hagler Bailly Pakistan with support from IFC in 2016. This model was updated for this study by combining the DRIFT DSSs used for assessing the EFlows of individual HPPs in the Jhelum-Poonch Basin since around 2010, namely the Kishanganga HPP, the Neelum-Jhelum HPP, the Gulpur HPP, the Karot HPP, and the Kohala HPP. The consolidated DRIFT DSS comprises 25 EFlow sites: 20 on the mainstem rivers (the Neelum, the Jhelum, and the Poonch) and five representing key groups of nullahs.

Scenarios Assessed

Impacts on the aquatic ecological resources were assessed using the DRIFT DSS. It allowed for the evaluation of scenarios comprising three levels of hydropower project development (excluding the nullahs), two levels of management of the downstream river reaches and key tributaries, and variations on HPP operations, including sediment flushing and peaking versus baseload power generation. Based on an assessment of changes in key indicators for each scenario, the DSS predicted overall river condition for 30 years into the future starting from 2012, where the intervening period is defined by the provisions of the scenario.

The three levels of HPP development were defined as:

1. Existing or under-construction HPPs
2. Committed HPPs, meaning detailed engineering is at an advanced stage and tariff application has been submitted or approved by the electricity regulator, or a letter of support has been issued by the government, at the engineering procurement and construction stage
3. Planned HPPs, meaning a feasibility study has been prepared and a letter of intent has been issued by the government, but detailed engineering has not started or is at an early stage and investors other than the initial developer have not been secured

The management levels were defined by peak or baseload power generation, EFlow releases, and the various management levels agreed to with HPP companies. By combining these factors, two management levels were defined as:

1. "Agreed," which incorporated the various management provisions agreed between the government and individual HPP companies
2. "High," which has more stringent protection levels for the environment than those in the "agreed" management level implemented throughout the basin; the protection measures include higher EFlow releases from the Neelum-Jhelum HPP (22.5 m^3/s instead of 9 m^3/s) and baseload, instead of peaking, operations at the Neelum-Jhelum HPP and the Kishanganga HPP

A stakeholder workshop was held in January 2018 to review and test the scenarios that encompass individual changes in flow regime, sediments, management, and migration of fishes.

Results

The overall ecosystem integrity of each river reach represented by an EFlow site in each scenario is summarized in **Table ES1**. Overall, the gradual increase in the number of hydropower projects in the Jhelum-Poonch Basin will be accompanied by:

- A decline in sand and gravel availability in the rivers, which may be offset to some degree by the flushing of sand-sized sediments; gravel, however, will not be flushed from the reservoirs for many years.
- An increase in the availability of cobble and boulders, which become exposed as sand and gravel is eroded away and not replaced after being trapped in upstream reservoirs.
- This effect is unlikely to persist for a great distance downstream of any HPP, particularly in the upper parts of the basin, because of the high sediment supply from hill slopes (landslides). It may become more problematic downstream, where there is less sediment supplied by the slopes and the cumulative impacts of many HPPs have a greater effect on supply.
- Habitat diversity will decrease because of reduced sediment supply and increased erosion. This is likely to affect breeding habitats as many spawning fish tend to favor gravel habitats.
- Habitat changes and the knock-on effects on other aspects of the river ecosystem, such as downstream riparian vegetation and macroinvertebrates serving as fish food, will deplete fish abundance.

Lessons Learned

While developing this strategy and during the planning, construction, and implementation of hydropower projects in the basin between 2015 and 2020, international practices for sustainable hydropower development were shared with HPP developers and government agencies to raise awareness and build capacity within the sector, with the goal of balancing power production and protecting environmental and social values of the basin. Development and implementation of biodiversity management plans and biodiversity action plans by HPPs have provided initial lessons learned in relation to assessing how well they work.

Table ES2 summarizes the lessons learned in the planning, construction, and operations of different HPPs.

Table ES1: Overall Ecosystem Integrity for each EFlow Reach Associated with Each Scenario

EFlows site/reach	Baseline integrity (2012)	Baseline (2012) Business As Usual	Existing and under construction		Committed		Planned	
			Management level		Management level		Management level	
			Agreed	High	Agreed	High	Agreed	High
Neelum River								
Line of Control	B/C	C	D	D	D	D	D	D
Surgun Nullah	B	C	C	C	C	C	C	C
Dudhnial	B/C	C	C	C	C	C	D	D
Athmuqam	C	D	D	D	D	D	D	D
Jagran Nullah	B/C	D	C	C	C	C	C	C
Nauseri	C	D	D	C	D	C/D	D/E	D
Panjgiran	C	D	E	D	E	D	E	D
Pattika Nullah	C	D	D/E	C	D/E	C	D/E	C
Dhanni	C	D	E	D	E	D	E	D
Muzaffarabad	D	E	E	E	E	E	E	E
Kunhar River								
Khanian	C	D	E	D	E	D	E	D
Paksair	C	D	E	C/D	E	D	E	D
Upper Jhelum River								
Upstream Kohala HPP	C	D	B	B	B	B	B/C	B/C
Subrey	C	D	C/D	C	C/D	C	C/D	C/D
Lower Jhelum River								
Ambor	C/D	E	E	D/E	E	E	E	E
Kohala	C/D	D/E	E	D	E	D	E	D
Mahl Nullah	C	D	D	B	D	C	D	C
Mahl Downstream	C	D	E	D	E	D	E	D
Azad Pattan	C	D	E	D/E	E	E	E	E
Kahuta Nullah	C	D	C	C	C	C	C	C
Hollar	C	D	D	D	E	D	E	D
Poonch River								
Kallar Bridge	C	D	C	Not run	C	Not run	D	Not run
Borali Bridge	C	D/E	D		D		D	
Gulpur Bridge	C	D/E	C		C		C	
Billiporian Bridge	C	D/E	B/C		B/C		B/C	

Note:

1. Key for ecosystem-integrity values: A: unmodified, B: slightly modified, C: moderately modified, D: largely modified, E: seriously modified, F: critically modified
2. For the Poonch River, only the "agreed" management level as outlined in the biodiversity action plan of the Gulpur HPP was run in the DRIFT model.

Table ES2: Lessons Learned and Recommendations for the Jhelum-Poonch River Basin

Topic	Lessons Learned
Conceptual design and prefeasibility	The Strategic Environmental Assessment (SEA) for hydropower development in AJK prepared by the International Union for Conservation of Nature (IUCN) helped stakeholders identify impacts and plan for mitigation early.
Timing of environmental and social impact assessment (ESIA) in project development	ESIAs need to be completed prior to government approval of projects.
Effectiveness of environmental regulation	Environmental protection agencies (EPAs) can help the public sector improve environmental design and performance of projects drawing on good practices adopted by the private sector.
Role of power purchaser and electricity regulator	Environmental costs should be identified, accounted for in project budgets, and included in tariff calculations.
Role of owners of projects financed by international lenders	The Gulpur HPP and other internationally funded projects provide application examples of high environmental and social standards set by international lenders, including the use of EFlow modeling. The lessons learned should be shared with other HPPs as examples of good practice to promote sustainable hydropower.
Role of owners of projects financed by other lenders	Environmental requirements should be consistent across HPPs.
Setting EFlows	EFlow levels should be set after a full assessment of the impacts.
Construction stage: restrictions to fish migration	Fish may be stranded downstream of HPP damsites during construction.
Construction stage: sealing of diversion tunnels	Impoundment or the commissioning of a reservoir needs to consider downstream impacts.
Construction stage: extraction of sediment from and dumping in rivers	The collection of sand and gravel as well as the dumping of sediment need additional regulation.
Operation stage: monitoring and adaptive management	HPPs should monitor indicators to evaluate project impacts over time, implement adaptive management if negative impacts are detected, and adopt emerging best practices where feasible.
Operations stage: emergency shutdown of powerhouse	HPPs should be prepared in case of emergency stoppage to prevent downstream impacts.
Operations stage: control of invasive fish species in reservoirs	Reservoirs must be managed.
Design and operations stage: transboundary projects	The transboundary impacts of HPPs should be assessed in ESIAs.

Recommendations for the Government

Recommendations for government action to achieve sustainable management of hydropower development in the Jhelum-Poonch Basin were developed through stakeholder engagements and studies summarized above. The recommendations are listed in the following **Table ES3** and detailed in **section 8** of this report. Implementation will require support from all basin stakeholders, including hydropower developers and NGOs.

Table ES3: Recommendations for the Government

Recommendation 1: Provincial environmental protection agencies (EPAs) should develop guidelines for hydropower projects on selecting and maintaining appropriate EFlows that are in line with the World Bank Group's *Good Practice Handbook on Environmental Flows for Hydropower Projects*. In addition, the EPAs should also develop guidelines and standard operating procedures for addressing emergency shutdown during project operations and require such procedures to be included in the ESIA.
Recommendation 2: The state and provincial environmental protection regulations in AJK, Punjab, and KP should be amended so that (i) there are direct linkages between environment and social cost allocation approved by the National Electric Power Regulatory Authority (NEPRA) and budgets allocated and used by project sponsors to comply with the ESIA or environmental social management plans (ESMPs), (ii) hydropower projects with a capacity under 50 megawatts (MW) should require an environmental impact assessment (EIA) if they are in highly sensitive ecological or socio-economic zones as identified in this strategy.
Recommendation 3: Amend policies, laws, and regulations to promote sustainable sediment mining from riverbed and banks. The basic principles to be followed will include protection of sensitive river habitats by restricting extent and type of mining to less sensitive areas to meet basic community needs and to protect livelihoods of poor and vulnerable mining communities.
Recommendation 4: A high level of protection should be maintained to protect the ecological resources of the Poonch River Mahseer National Park. The Mahl River should also be declared a protected area. Other important tributaries with high ecological sensitivity should be identified and excluded from or proceed with minimal hydropower development.
Recommendation 5: Strengthen the capacity and capability of government departments to implement effective environmental management and protection by allocating additional budget and human resources.
Recommendation 6: Surveys for different fish species should be conducted to monitor the status of fish population in the river and tributaries. Based on fish population estimates, a sustainable fishing program can be initiated in selected areas.
Recommendation 7: Government departments should support the hydropower developers to develop a basin-wide sediment-management strategy addressing the community needs for sand and gravel.
Recommendation 8: Mitigate impacts from the construction and operation of transmission lines. The provincial EPAs should develop guidelines for the planning and construction of transmission lines, particularly in sensitive and protected areas.
Recommendation 9: Terms of reference for full ESIA studies of relevant HPPs should include the cumulative assessment requirements and conform to IFC Performance Standards and the Asian Development Bank's Safeguard Policy Statement.
Recommendation 10: Enhance the protection of aquatic ecological resources from anthropogenic impacts such as illegal fishing, sediment extraction, and pollution. Increase coordination among relevant government departments.
Recommendation 11: Guidelines for reservoir management should be formulated. Selective commercial and recreational fish harvesting may be permitted, but the reservoirs should not be stocked with exotic fish species. Managers and local fishers should be trained to control invasive fish species. Reservoirs should be managed to protect migratory birds and developed for recreational activities if appropriate.
Recommendation 12: Environmental regulators, particularly the EPAs, should be consistent in evaluating the environmental assessment and performance of hydropower projects irrespective of ownership. Developers should be encouraged to follow international good practices for environmental management, mitigation, and monitoring.
Recommendation 13: A methodology should be developed for calculating the cost of mitigating negative environmental impacts of a HPP and incorporating that cost into the electricity tariff. The capacity of NEPRA staff should be enhanced to address emerging concerns in the environmental design of HPPs.
Recommendation 14: The SEA prepared by IUCN (Annandale and HBP 2014) should be updated by the government planning departments to include the Kunhar Basin and incorporate latest information.

Recommendations for Hydropower Developers

Recommendations for developers to achieve sustainable management of hydropower in the Jhelum-Poonch Basin were devised using the studies summarized above and by consulting all relevant stakeholders. The recommendations are listed in the following **Table ES4** and detailed in **section 9** of this report. Implementation of these recommendations will require support from all stakeholders in the basin including government departments and NGOs.

Table ES4: Recommendations for Hydropower Developers

Recommendation 1: Ensure HPPs are designed to balance power-generation benefits and environmental and social impacts by including assessment of environmental and social risks during the feasibility stage.
Recommendation 2: Both public and private-owned HPPs should develop and implement a biodiversity action plan or biodiversity management plan in line with accepted international good practices.
Recommendation 3: Develop a stakeholder engagement plan and a grievance redress mechanism in line with accepted international good practices.
Recommendation 4: Set up a database for the Jhelum-Poonch Basin to allow storage and access of data on hydrology, ecology, geomorphology, water quality, climate, socio-economics, and hydropower projects.
Recommendation 5: Contribute toward the establishment of a watershed management program to reduce erosion in the catchments and flow of pollutants into the river.
Recommendation 6: If HPPs are close to each other on a main river or tributary nullahs, proponents should consult each other about project design to enable synergistic development. Such consultation should be mandatory even if project initiation schedules are not synchronized.
Recommendation 7: Contribute toward the establishment of a river ecology institute to conduct research on river biodiversity, impacts of HPPs, and mitigation options.
Recommendation 8: HPP staff and consultants should enhance their environmental management and protection capabilities by staying abreast of latest studies and research as well as participating in training and capacity-building initiatives.
Recommendation 9: A basin-wide sediment management strategy should be developed for all committed HPPs in the Jhelum-Poonch Basin.
Recommendation 10: Collaborate on issues of mutual concern through the Hydropower Developers Working Group (HDWG) and share lessons learned and good industry practices.
Recommendation 11: Mitigate construction-phase impacts by transporting fish from downstream to upstream of the dam, developing an impoundment or a commissioning plan, and banning sediment extraction and dumping into the river.
Recommendation 12: Developers should devise a standard operating procedure to address cases of accidental or emergency stoppage of water flow during operation.
Recommendation 13: Develop and implement a monitoring and evaluation plan as well as adaptive measures if there are significant negative impacts from HPPs on ecology and ecosystem services.

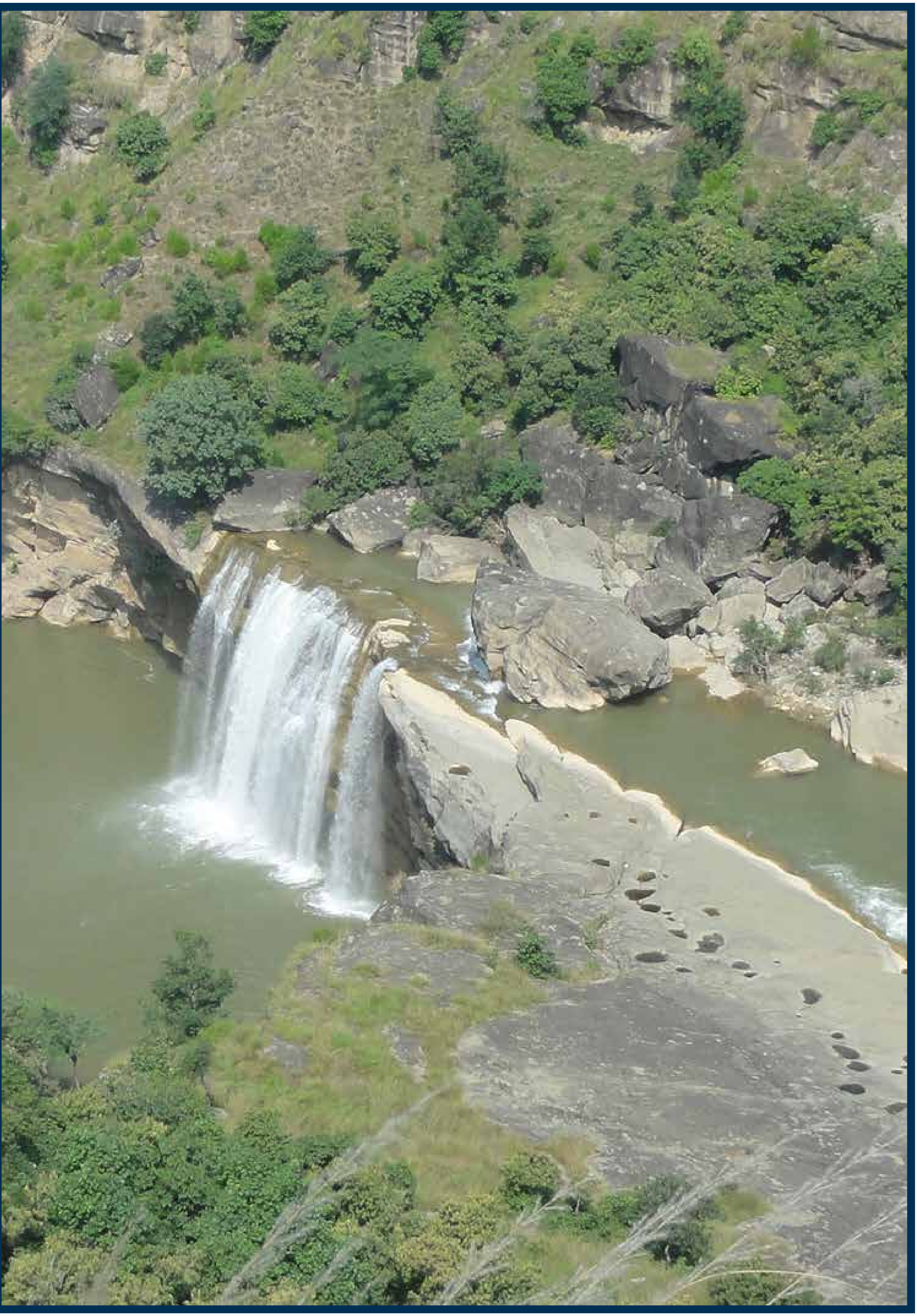
ABBREVIATIONS

ADB	Asian Development Bank
AJK	Azad Jammu and Kashmir
AJKEPA	Azad Jammu and Kashmir Environmental Protection Agency
AJKFWD	Azad Jammu and Kashmir Fisheries and Wildlife Department
BAP	Biodiversity Action Plan
BAU	Business As Usual
BMP	Biodiversity Management Plan
CIA	Cumulative Impact Assessment
CMS	Convention on Migratory Species
CNPPA	Commission on National Parks and Protected Areas
CPPAG	Central Power Purchasing Agency Guarantee Limited
DRIFT	Downstream Response to Imposed Flow Transformations
DSS	Decision Support System
EFlow	Environmental flow
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EPD	Energy and Power Department
EPT	Ephemeroptera, Plecoptera, Tricoptera
ESIA	Environmental and Social Impact Assessment
GoAJK	Government of Azad Jammu and Kashmir
GoKP	Government of Khyber Pakhtunkhwa
GOP	Government of Pakistan
HBP	Hagler Bailly Pakistan
HDWG	Hydropower Developers Working Group
HPP	Hydropower Project
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IHA	International Hydropower Association
IRRE	Institute for Research on River Ecology

IUCN	International Union for Conservation of Nature
KE	Karachi Electric
KESC	Karachi Electric Supply Company
KP	Khyber Pakhtunkhwa
NEPRA	National Electric Power Regulatory Authority
NGO	Non-governmental organization
NORSAR	Norwegian Seismic Array
NTDC	National Transmission and Despatch Company
Pak-INDC	Pakistan's Intended Nationally Determined Contribution
PDO	Power Development Organization
PED	Punjab Energy Department
PEDO	Pakhtunkhwa Energy Development Organization
PPDCL	Punjab Power Development Company Limited
PPIB	Private Power and Infrastructure Board
Pro	Protection in terms of management interventions to reduce non-flow related impacts on the riverine ecosystem
SEA	Strategic Environmental Assessment
SF	Sediment Flush
SIDRI	Shanghai Investigation, Design & Research Institute Co. Ltd.
UNESCO	United Nations Educational, Scientific and Cultural Organization
VEC	Valued Environmental Components
WAPDA	Water and Power Development Authority
WBG	World Bank Group
WCD	World Commission on Dams
WCED	World Commission on Environment and Development
WCMC	World Conservation Monitoring Centre
WWF	World Wildlife Fund

List of Units

g	|	Gram
km	|	Kilometer
km^2	|	Square kilometer
kV	|	Kilovolt
m	|	Meter
m^3/s	|	Cubic meter per second
mm	|	Millimeter
MW	|	Megawatt
No.	|	Number
°C	|	Celsius



1. INTRODUCTION

Over the last decade, the Government of Pakistan (GOP) prioritized hydropower development across all territories in its control to overcome massive energy shortfalls estimated at 8,500 megawatts (MW) in 2012 (Dawn 2012). Pakistan is now on the path to overcoming this energy crisis through increased generation and higher transmission capacity. Between 2013 and 2019, several energy-generating projects were approved, with the installed capacity of electricity reaching 35,972 MW in 2020. Hydropower made up 30.9 percent of electricity generation in the same year, up from 25.8 percent in 2019 (GOP 2020).

IFC is financing multiple hydropower projects—some through equity investments—in the Jhelum-Poonch Basin in Pakistan and Pakistan-Administered Kashmir (Azad Jammu and Kashmir). It also has an equity investment in China Three Gorges South Asia Investment Ltd. that acquire, develop, and operate numerous renewable-power-generation projects in Pakistan, including the Patrind HPP (147 MW) on the Kunhar River, the Gulpur HPP (102 MW) on the Poonch River, and the Mahl HPP (640 MW), Karot HPP (720 MW), and Kohala HPP (1124 MW) on the Jhelum River. The World Bank and IFC are committed to minimizing the impacts of their funded investments and commissioned Hagler Bailly Pakistan (HBP) in 2017 to develop a strategy for sustainable hydropower development in the basin that is based on a high-quality multi-stakeholder engagement process. The strategy was revised in 2020, incorporating findings of additional studies carried out in the basin and comments from key stakeholders.

1.1 Sustainable Development

According to the World Commission on Environment and Development (1987), sustainable development is defined as meeting "the needs of the present without compromising the ability of the future generations to meet their own needs." Economic development and human well-being are dependent on the use of natural resources, which, if exploited beyond limit, can degrade to an extent that they can no longer support economic development. This can lead to inequality, poverty, and conflicts among communities and nations that affect future generations. Systematic consideration of sustainable development in recent literature defines the concept in various parameters: environment, economy, equity, poverty, quality of life, society, and spatial extents.

Hydropower projects have brought many benefits to humanity, but they also modify the river's flow regime, creating knock-on effects on sediment and the river's chemical and thermal regimes, biota, and ecosystem services. The more the natural flow regime is altered, the greater the response of the ecosystem and the impacts on people. Hydropower projects are thus a mixed blessing: on the one hand, they bring secured water supply, hydroelectric power, and reduced greenhouse-gas emissions, but on the other hand, they cause declining fisheries and water quality, failing estuaries, and the loss of highly productive floodplains. Large hydropower projects can also displace many people and increase the flood risk for nearby villages. Sustainable hydropower development needs to balance these benefits and costs to minimize negative impacts.

Developing hydropower or other renewable-energy sources can reduce Pakistan's dependence on oil and gas, cutting greenhouse-gas emissions to help the country fulfill its commitment to the United Nations Framework Convention on Climate Change's Paris Agreement (GOP 2016). However, it is also important to mitigate and minimize the negative environmental and social impacts associated with hydropower development.

The strategy for sustainable hydropower development in the Jhelum-Poonch Basin outlined in this report is a first step toward achieving this goal. It aligns with Pakistan's development policies and commitments to adopt the United Nations' Sustainable Development Goals.[1] The strategy also embodies the principles of Pakistan's National Biodiversity Strategy and Action Plan (GOP 2017a), which highlights the need to protect aquatic flora and fauna from the negative impacts of hydropower development. Furthermore, it is based on a comprehensive stakeholder engagement process which ensures diverse views are incorporated.

1.2 Objectives

The specific objectives of the strategy for sustainable hydropower development in the Jhelum-Poonch Basin are as follows:

[1] For more information, see the website of National Initiative for Sustainable Development Goals at https://www.sdgpakistan.pk/.

- Provide an overview of the baseline conditions in the area of management, including physical conditions, aquatic and terrestrial ecological resources, and socio-economic profile
- Evaluate the impact of hydropower project (HPP) development on the sediment profile, ecological resources, and ecosystem services in the area of management
- Promote the sustainable and wise use of natural resources in relation to hydropower development
- Provide good practice for existing and potential developers to strategically manage the negative impacts of hydropower development
- Provide recommendations for government departments to minimize risks and manage negative impacts of hydropower development
- Outline lessons learned for protecting the environment, preserving ecological resources, and managing stakeholder concerns during the planning, construction, and operation of HPPs
- Enhance the benefits of HPPs for communities and ecosystems through participatory planning and capacity building
- Carryout a comprehensive multi-stakeholder engagement process within Pakistan.

1.3 Area of Management

Figure 1 shows the Jhelum-Poonch Basin, defined as the catchment draining into the Mangla Reservoir up to the Mangla Dam. The basin, consisting of the Upper Jhelum River and its tributaries, is divided into six subbasins:

- **Upper Jhelum Basin—**including the Jhelum River upstream of Wular Lake, which regulates flow and sediment
- **Middle Jhelum Basin—**including the Jhelum River immediately downstream of Wular Lake and upstream of Domel before the confluence of the Neelum and Kunhar tributaries with the Jhelum
- **Lower Jhelum Basin—**downstream of Domel where the Neelum and Kunhar tributaries join the Jhelum River and up to the Mangla Dam
- **Neelum Basin—**including the Neelum River, a large tributary of the Jhelum River, up to its confluence with the main Jhelum River
- **Kunhar Basin—**including the Kunhar River, a large tributary of the Jhelum River, up to its confluence with the main Jhelum River
- **Poonch Basin—**including the Poonch River upstream of its confluence with the Mangla Reservoir
- The Kanshi River catchment, which also drains into the Mangla Reservoir, has been excluded.[2]
- The subbasins are defined based on changing hydrological characteristics, including:
  - » Valley width and bed slope, thus shape of the river
  - » Additions of major tributaries that affect flow, temperature, and sediment
  - » Climatological features, such as variations in summer and winter precipitation (rainfall and snowfall), temperatures, and presence and extent of glaciers

The area of management includes the subbasins of the Jhelum-Poonch Basin falling within the territory of Pakistan (**Figure 1**).

Administratively, the area of management includes the state of Azad Jammu and Kashmir (AJK), three districts of Khyber Pakhtunkhwa (KP), and one district of Punjab. The Indian-administered Kashmir across the Line of Control has been excluded from the area of management because the stakeholders included in this study, including government departments, do not have management control over this area. The administrative boundaries of the area of management are shown in **Figure 2**.

Azad Jammu and Kashmir is an independent political entity within Pakistan with its own parliamentary government headed by the president. Administratively, AJK is divided into three divisions and 10 districts. Main rivers running through the state include the Neelum, the Jhelum, and the Poonch (GoAJK 2019).

Khyber Pakhtunkhwa is one of Pakistan's northwestern administrative provinces. KP is the third-largest province by both its population and economy size. It has seven divisions, 25 districts, and 71 tehsils (GOP 2017b).

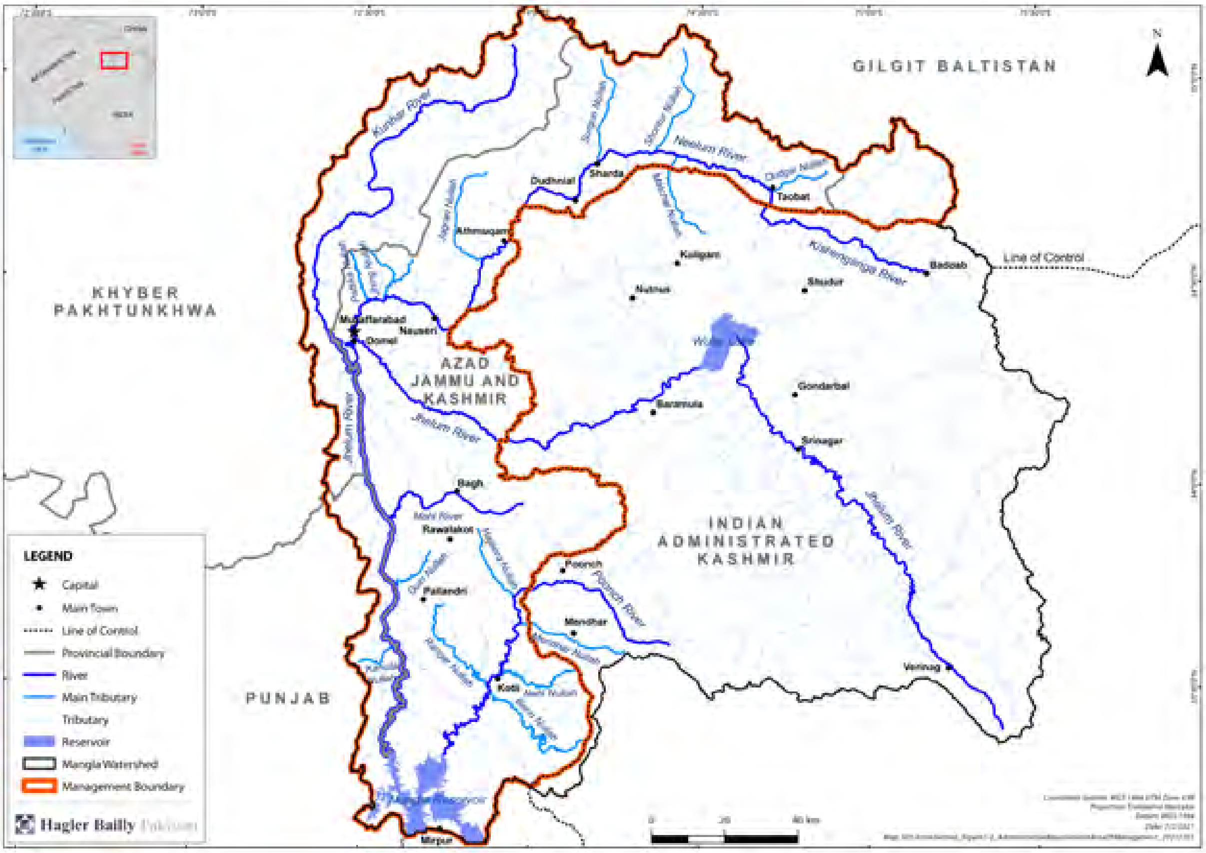
Punjab is Pakistan's most populous province and second-largest by area. Administratively, Punjab is divided into nine divisions and 36 districts (GOP 2017b).

An overview of the socio-economic conditions in the area of management are outlined in Annex E.A of **Annex E**.

[2] The Kanshi River catchment has been excluded since there are no HPPs planned in this basin. The catchment is already highly degraded and flows are insignificant.

Figure 1: River Basins in Area of Management

Figure 2: Administrative Boundaries in Area of Management



Note: The Jhelum River makes the boundary between the state of AJK and the KP and Punjab provinces, which can be observed on the western side of the area of management.

1.4 Hydropower Projects in the Jhelum-Poonch Basin

The hydropower projects in various stages of planning and construction in the area of management can be classified into the following categories:

- *Operational*: This includes the HPPs that are in operation.
- *Under construction*: This includes HPPs that are under construction but not yet operational.
- *Committed*: HPPs that have yet to be constructed but detailed engineering is at an advanced stage; the tariff application at the engineering, procurement, and construction stage has been submitted or approved by the electricity regulator, or a letter of support has been issued by the government.
- *Planned*: HPPs whose construction will likely commence within 10 to 20 years; feasibility has been prepared and a letter of intent has been issued by the government, but detailed engineering has not started or is at an early stage; investors other than the initial developer have not been secured.

Table 1 lists all HPPs in the area of management, while **Figure 3** shows them on a map.

Table 1: Status and Capacity of Hydropower Projects in the Jhelum-Poonch Basin

Subbasin	HPP	Planned capacity (MW)**	Operational	Under construction	Committed	Planned
Neelum	Kishanganga*	330	✓			
	Dudhnial	960				✓
	Ashkot	300				✓
	Athmuqam	450			✓	
	Neelum-Jhelum	969	✓			
Kunhar	Naran	188				✓
	Batakundi	96				✓
	Suki Kinari	870		✓		
	Balakot	300			✓	
	Patrind	147	✓			
Middle Jhelum	Lower Jhelum*	105	✓			
	Uri I*	480	✓			
	Uri II*	240	✓			
	Chakothi-Hattian	500				✓
	Kohala	1124			✓	
	Mahl	640			✓	
Lower Jhelum	Azad Pattan	701			✓	
	Karot	720		✓		
Poonch	Gulpur	102	✓			
	Sehra	130				✓
	Rajdhani	132				✓
	Parnai*	37	✓			

Note: Table shows the status of HPPs in 2020.
* Outside the area of management across the Line of Control in India
** The capacity of planned hydropower projects has not yet been finalized and may change

Figure 3: Hydropower Projects in the Jhelum-Poonch Basin

1.5 Regulatory and Institutional Framework

Protecting the environment and ecosystem services provided by the river is central to ensuring sustainable hydropower development. This section outlines the policies, laws, regulations, and the institutional framework relevant to both hydropower development and environmental conservation. Detailed information is available in **Annex A**.

1.5.1 Policies, Laws, and Plans for the Power Sector

Several national and provincial policies and legislations govern the development and distribution of hydropower development in the area of management, which covers the state of AJK and the two provinces of KP and Punjab.

The GOP announced a National Power Policy in 2015, offering enhanced incentives and simplified processing to produce affordable electricity for socio-economic development and bridge the demand-supply gap; the government urges local and international investors to develop power projects. Also governing the development of hydropower projects in the country is Water Vision 2025, a national water resource and hydropower development program by Pakistan's Water and Power Development Authority (WAPDA). The program aims to organize and prioritize HPPs in the short, medium, and long term to meet the country's power deficits (Siddiqui 2008).

Hydropower development in the state of AJK is governed chiefly by the Power Generation Policy 2015[3] formulated by Pakistan's Ministry of Water and Power. In Punjab, the Punjab Power Policy 2006 (revised in 2009) outlines a policy framework for the development of power generation in both public and private sectors. In Khyber Pakhtunkhwa, the Hydropower Policy 2016 offers enhanced incentives and simplified processing for setting up power plants to generate affordable electricity and bridge the demand-supply gap.

[3] Policy is available at the official website of Private Power & Infrastructure Board of Government of Pakistan: https://www.ppib.gov.pk/policies/Power%20Generation%20Policy%202015%20small.pdf.

1.5.2
Structure of Power Sector

The power sector in Pakistan consists primarily of two systems: corporatized generation, transmission and distribution companies that have been formed out of the former vertically-integrated monolithic power utility, the Water and Power Development Authority (WAPDA), and the vertically-integrated K-Electric (KE), formerly Karachi Electric Supply Company (KESC). WAPDA, an autonomous body and a federal institution, came into existence by virtue of an Act of Parliament in 1958 for the purpose of coordinating and providing a unified direction to water and power development schemes in all territories under Pakistan's control including AJK. The Ministry of Energy is a Pakistan Government's federal and executive level ministry and provides the policy framework and administrative oversight for the operation of the power sector, excluding the nuclear based power plants.

In AJK, the Electricity Department was developed to promote electricity and improve financial effectiveness of the state. The Department is responsible for assisting the state in implementation of overall government policies related to power/electricity. The Government of AJK established Power Development Organization (PDO) (previously Hydro Electric Board) in 1989, to plan and to undertake development of identified hydro potential. The PDO is responsible for developing hydropower potential of the state and doing so by especially encouraging private sector involvement. In Punjab, the Punjab Energy Department (PED) is responsible for regulation and policy formulation regarding power sector with support from Punjab Power Development Board (PPDB) and Punjab Power Development Company Limited (PPDCL). The energy portfolio of the provincial government in the Khyber Pakhtunkhwa province is managed by the Energy and Power Department (EPD) and has two technical agencies working under it, the Pakhtunkhwa Energy Development Organization (PEDO) looks after issues relating to electricity generation, transmission and distribution in the province while the Office of the Inspectorate of Electricity administers the implementation of the Electricity Act 1910 and Electricity Duty Rules 1962 as well as performs other regulatory and certification functions.

1.5.3
Regulatory Framework for Environmental Protection

The Pakistan Environmental Protection Act 1997 empowers the government to frame relevant regulations. In addition, the National Environmental Policy 2005 aims to provide an overarching framework to conserve, restore, and manage the country's environmental resources and address environmental issues, such as pollution of air and freshwater bodies, waste management, deforestation, loss of biodiversity, desertification, natural disasters, and climate change. However, the provinces have sole authority and responsibility to legislate on environment and ecology following devolution through the 18th Constitutional Amendment in 2010. The AJK Environmental Protection Act 2000 is the principal legislative tool used for regulating environmental protection in the state. In Punjab, the Punjab Environmental Protection Act 1997, amended in 2012, broadly governs regulations over environmental protection, including environmental impact assessments and prohibition of certain discharges, emissions, and hazardous materials. In Khyber Pakhtunkhwa, the KP Environmental Protection Act 2014 covers a broad range of issues such as air, water, and noise pollution as well as industrial-liquid effluent and hazardous waste.

1.5.4
Institutional Framework for Environmental Protection

The natural resources within AJK, KP, and Punjab are the responsibility of specific government departments, such as wildlife and fisheries as well as forestry. Together, they form the institutional framework for governance and regulation of natural biological resources. In AJK, the AJK Wildlife and Fisheries Department has the joint responsibility to protect, preserve, conserve, and manage terrestrial and aquatic resources and habitats, while in Punjab and KP, there are independent wildlife and fisheries departments. The provinces and AJK have their own forest department to protect and preserve forests. The provincial environmental protection agencies administer and implement provincial environmental protection acts, hold the mandate to review the Initial Environmental Examination and Environmental Impact Assessment reports and issue the no-objection certificates. They also prepare, revise, and enforce the National Environmental Quality Standards for industries, municipalities, and vehicular emissions.

1.5.5
IFC Performance Standards

IFC's Policy on Environmental and Social Sustainability outlines its environmental and social requirements for projects. IFC's eight Performance Standards of 2012 provide guidance to the management of social and environmental risks and impacts as well as enhance development opportunities in private sector financing among IFC member countries.

1.5.6
Asian Development Bank's Safeguard Policy Statement 2009

Built upon the Asian Development Bank's (ADB) Involuntary Resettlement Policy (1995), the Policy on Indigenous Peoples (1998), and the Environment Policy (2002), the Safeguard Policy Statement was approved in 2009. The statement outlines operational policies that seek to avoid, minimize, or mitigate adverse environmental and social impacts, including protecting the rights of those likely to be affected or marginalized by the developmental process.

1.5.7
Hydropower Sustainability Guidelines

The Hydropower Sustainability Guidelines on Good International Industry Practice (IHA 2018) define expected sustainability performance for the hydropower sector across a range of environmental, social, technical, and governance topics.

1.5.8
World Commission on Dams Guidelines

The World Commission on Dams (2000) established the most comprehensive guidelines for dam building. The commission's final report describes an innovative framework for planning water and energy projects to protect the environment and affected people as well as to ensure an equitable distribution of benefits from dam development.

1.6
Stakeholder Identification and Consultation

Stakeholders are groups or individuals that can change or be affected by a project's outcome. ADB's Safeguard Policy Statement (2009) and IFC Performance Standards specifically identify affected people, concerned non-governmental organizations (NGOs), and government as prospective stakeholders to a project.

The stakeholders relevant to the development and implementation of the strategy in this report were identified and mapped as primary or secondary, using the methodology described in **Annex B**.

Important stakeholders at the federal level include WAPDA, the National Electric Power Regulatory Authority (NEPRA), and the Pakistan Environmental Protection Agency (EPA). At the provincial level, the most important institutional stakeholders are the energy and power departments and their related sub-departments, fisheries and wildlife departments, provincial EPAs, and mining departments.[4] Also important are the hydropower-project owners and developers, international development institutions such as IFC and ADB, environmental NGOs, researchers, and academia.

Consultations with key stakeholders were conducted throughout the process of developing this strategy. An inception workshop was held on October 18, 2017, as a first step of the study and all stakeholders were invited to provide feedback on its terms of reference. The workshop was organized by IFC and consulting firm Hagler Bailly Pakistan (HBP) in Islamabad. Participants included representatives from major hydropower developers in the basin; forest, fisheries, and wildlife departments; the EPAs of AJK, KP, and Punjab; the Ministry of Water and Power; WAPDA; power planners; researchers and scientists; and environmental NGOs active in the basin. The workshop enabled participants to gain a collective understanding of the challenges and trade-offs associated with hydropower development in the Jhelum-Poonch River Basin. They also recommended ways to minimize negative environmental and social impacts from such development.

To consider stakeholder concerns related to hydropower development in the basin, the environmental and social impact assessments (ESIAs) listed in **section 1.7** were reviewed. The ESIAs include consultation logs of meetings conducted with local communities and institutional stakeholders such as government departments, NGOs, and project owners and developers.

In May 2018, the draft strategy report was shared with all stakeholders in a workshop held in Islamabad to present its salient features and gather feedback. In January 2019, IFC organized a working group to prioritize the recommendations outlined in the strategy. The session was attended by more than 20 participants, including hydropower developers and government representatives. They were again contacted in March 2020 and their comments and feedback were incorporated into preparing the final version of this report and this final product was supported by all stakeholders.

[4] Mining departments issue permits for the mining of sediment from the riverbed and banks.

1.7 Sources of Information

This report was compiled based on a literature review of existing information including books, scientific journals, newspaper articles, and ESIAs conducted for various HPPs. The following HBP reports were consulted:

- Sustainable Sediment Mining and Management Plan for the Poonch River Mahseer National Park, 2020, for Mira Power Ltd.
- ESIA of the Mahl Hydropower Project, March 2018, for Shanghai Investigation Design & Research Institute Co., Islamabad
- ESIA of Azad Pattan Hydropower Project, December 2017, for Azad Pattan Power (Private) Ltd., Islamabad
- ESIA of the Balakot Hydropower Project, August 2017, for ADB
- ESIA of the Kohala Hydropower Project, March 2017, for Kohala Hydro Company (Private) Ltd.
- Biodiversity Management Plan of the Karot Hydropower Project, February 2016, for Karot Power Company (Private) Ltd.
- Biodiversity Strategy for the Jhelum River Basin—Preparatory Phase, Fish Surveys in Tributaries, September 2016, for IFC
- Monitoring and Evaluation of the Biodiversity Action Plan for the Poonch River Basin, 2015–2020, for Mira Power Ltd.
- Environmental Flow Assessment of the Neelum-Jhelum Hydroelectric Project, Volume 2, March 2015, for Pakistan Commissioner for Indus Waters
- ESIA of the Gulpur Hydropower Project, September 2014, for Mira Power Ltd.
- Strategic Environmental Assessment of the Hydropower Plan for Azad Jammu and Kashmir, 2014, for the International Union for Conservation of Nature (IUCN), Islamabad
- Environmental Assessment of the Neelum River Water Diversion, May 2011, for Pakistan Commissioner for Indus Waters

In addition, field surveys were conducted to collect ecological and socio-economic information from areas where data gaps were identified (HBP 2017b); such information has been included in this report.

1.8 Organization of This Report

The structure of this final strategy report is as follows:

Section 2 provides an overview of the climate, hydrology, and sediment profile in the area of management.

Section 3 summarizes the aquatic and terrestrial ecological resources reported from the area of management.

Section 4 provides an overview of the socio-economic conditions.

Section 5 outlines the impacts from the construction and operation of multiple hydropower projects on the sediment profile of the basin.

Section 6 outlines the impacts from the construction and operation of multiple hydropower projects on the ecological resources of the basin.

Section 7 outlines lessons learned for managing and minimizing environmental risks during the planning, construction, and operation of hydropower projects in the Jhelum-Poonch Basin.

Section 8 provides recommendations for government departments to minimize the negative impacts of hydropower development.

Section 9 provides recommendations for project owners and developers to minimize the negative impacts of hydropower development.

2. OVERVIEW OF PHYSICAL CONDITIONS

This section provides a summary of the physical conditions in the Jhelum-Poonch Basin with a focus on the area of management. Details are provided in **Annex C**.

2.1 Topography

The Jhelum River catchment up to the Mangla Dam is located at the western edge of the Higher Himalayan range. Based on the topography, the catchment area can be subdivided into four units as follows:

- Alpine area at the northernmost area of this region, with an altitude of around 3,500 meters
- Medium- and high-mountain area in the northern and central part of this region, with an altitude of about 2,000 meters; to the east is the Kashmir Basin, and to the west the Pansavart Basin
- Low-to-medium mountain area in the central part of this region; to the west is the Potowar plateau with an altitude of about 500 meters, and to the east is the Hazara-Kashmir Syntaxis with an altitude of about 2,500 meters
- Plain area toward the south of this region, with an altitude of about 200 meters

2.2 Geology, Soils, and Seismicity

This section presents information on the geology, soils, and seismicity in the area of management.

2.2.1 Lithology

The area of management is located on the Himalayan thrust nappe. Most of the strata in the north of the area comprise Precambrian metamorphic igneous sedimentary rocks, while the southern part of the area is dominated by Tertiary sedimentary rocks. Other rock types include Mesozoic sedimentary, Mesozoic acid, intermediate intrusive, and metamorphic.

2.2.2 Tectonics

The area of management is in a seismically active zone affected by the continuing northward drifting of the Indian plate and its subduction below the Eurasian plate. Several regional and local faults are active in the area. The area of management is at the southern foot of the Himalayas, the world's youngest and largest orogenic belt formed by the collision between the Indian and Eurasian plates. There are region syntaxis with sharp turns at both the east and west ends of the Himalayas. The western syntaxis consists of the following tectonic units (from north to south): the Karakoram plate; the Karakoram suture zone; the Kohistan-Ladakh island arc; the Indus River-Yarlung Zangbo River suture zone and the Nanga Parbat-Haramosh massif; the faults at the primary boundary of the Himalayas, and the Hazara-Kashmir Syntaxis.

The major regional thrust faults related to intercontinental collision include the Main Mantle Thrust, the Main Boundary Thrust, the Panjal Thrust, the Main Central Thrust, and the Himalayan Frontal Thrust. The planes of these faults run almost parallel to the collision boundary.

2.2.3 Earthquakes and Seismicity

The depth of the earthquake focus in this region is within 1 to 250 kilometers (km). Many are moderate-to-deep-focus earthquakes. Between 34°N and 36°N, the depth of the earthquake focus increases gradually (from south to north) from between 70 and 100 km to between 250 and 300 km to form an earthquake-focus belt that inclines northward. This shows the region is located in an area where the Indian plate collided with the Eurasian plate.

2.2.4 Landslides

Heavy rainfall and associated flooding increase the risk of landslides. According to information provided in the ESIA of the Mahl HPP (HBP 2018a), local communities reported that the incidence of landslides following heavy rainfall, particularly after the 2005 earthquake, has increased. Moreover, during the physical field surveys performed in July 2017 for this study, numerous landslides, of Quaternary soil deposits, were observed following relatively heavy rainfall.

2.3 Climate

This section provides an overview of the climate in the Jhelum-Poonch Basin, with four identifiable seasons as follows:

Summer (mid-March to mid-June)

- Characterized by high temperatures, moderate rainfalls and humidity, and high-speed winds

Summer monsoon (mid-June to mid-September)

- Characterized by high temperatures (although milder than the summer), significantly high rainfalls, high humidity, and moderate-speed winds (slightly lower than summer)

Post-monsoon summer (mid-September to mid-November)

- Characterized by moderate temperatures, low rainfalls, moderate humidity, and low-speed winds

Winter (mid-November to mid-March)

- Characterized by very low temperatures, moderate rainfalls (with an increasing amount at the end of winter), relative humidity higher than during post-monsoon summer, and moderate-speed winds

2.3.1 Temperature and Precipitation

This section provides an overview of the temperature and precipitation of the Jhelum-Poonch Basin. Information is derived from the WorldClim 2 dataset (Fick and Hijmans 2017). The dataset is expected to be more representative of the catchment compared to point-gauging data because it is gridded and uses a large regional network of gauges and covariates, including elevation and distance to the coast as well as satellite covariates (maximum and minimum land-surface temperature and cloud cover).[5]

An evaluation of the mean monthly temperatures in the subbasins of the Jhelum-Poonch Basin shows:

- The Neelum Basin is the coldest subbasin with the mean monthly winter temperature falling as low as -8°C and the mean monthly summer temperature ranging between 14°C and 15°C.
- In the Kunhar Basin, the coldest temperatures are experienced from December to February where the mean monthly temperature can fall as low as -6°C, while the highest mean monthly temperatures are experienced from June to August (14°C to 16°C).
- In the Upper Jhelum Basin, the mean monthly temperature varies between -3°C and 18°C.
- In the Middle Jhelum Basin, the mean monthly temperature varies from 1°C in January to 21°C in June, July, and August.
- The Poonch Basin is a comparatively warmer subbasin where the mean monthly temperature ranges from 5°C in January to 24°C in June and July.
- The Lower Jhelum Basin is the warmest basin where the mean monthly temperature varies from 8°C in January to 28°C in June.

The Jhelum-Poonch Basin lies at the edge of the core monsoon region of Pakistan and western Himalaya (Latif and Syed 2015), experiencing the South Asian summer monsoon, also known as the Southwest monsoon. Orography and the fact that the region is at the northwestern extent of the South Asian summer monsoon creates two distinct precipitation regimes in the basin (Archer and Fowler 2008). In the northern part of the basin, there is a single peak in spring precipitation, but the summer peak is weakly developed. In the southern part, the monsoon rains dominate and the summer peak is better developed (Archer and Fowler 2008).

2.4 Hydrology

The mean monthly flows within the Upper Jhelum and its tributaries do not completely correspond to the precipitation, particularly for winter. This is because the catchment experiences snowfall associated with the western disturbances in winter months, which does not immediately report to the river. In spring, as temperatures start to increase, snow begins to melt and the flow increases, compounding the impact of South Asian summer monsoon rainfall. There is a positive relationship between flow and summer precipitation (rainfall), and a negative relationship between flow and temperature.

[5] Satellite covariates marginally improve the dataset and ground-based weather station data is of more value.

The catchment is not extensively glaciated, as with the Karakoram or the Central Himalaya, therefore glacial melt is not expected to contribute to the flow. However, a larger number of glaciers are present in the Upper Jhelum, Poonch, and Naran Basins compared to the Middle and Lower Jhelum Basin where there are fewer glaciers.

Flows of the Jhelum River, upstream of its confluence with the Neelum River (Domel Station), are higher than the Neelum (Muzaffarabad Station) from January to April. However, the flow of the Neelum exceeds that of the Jhelum from May to August and thereafter the flow of both rivers remains almost equal up to November. The flow in the Neelum during summer is higher since the river is fed by snowmelt and rain, whereas the Jhelum River, prior to its confluence with the Neelum, has greater glacial melt from the Higher Himalaya and the Pir Panjal Range. Differences in the start of spring melt exist within the basin.

To the south of the catchment (Kohala and Chatter Kalas gauging stations), October to February is the low-flow period, while the flood season is from April to August. March is the transitional phase from dry to wet season and September is the transitional month from wet to dry season.

2.4.1 Land-Cover Changes

The Jhelum-Poonch Basin includes territories in both India and Pakistan. About 48 percent of the basin lies in Pakistan and the rest lies in India. Satellite imagery was used to identify the land-cover classes or habitat types in the Jhelum Basin. These land-cover maps for 1993 and 2014 were assessed and statistically analyzed for changes at the basin and subbasin levels.

The methodology used is provided in Annex C.A of **Annex C**. A brief summary of results is outlined below. The land-cover classes identified are listed in **Table 2**.

The key findings are summarized below:

- Overall, forests and scrubs were the most dominating land-cover feature in 1993, but bare land took their place by 2014. Forests and scrubs decreased by 6.6 percent, while bare land increased by 8.6 percent during this period. The same trend can be observed in all subbasins of the Jhelum Basin, indicating that deforestation and cutting of scrubs has increased over time.
- Overall, there has been a small reduction in grasses except for the Lower Jhelum Basin (in Pakistan) and the Middle Jhelum Basin.
- The area of large waterbodies observed is almost the same in 1993 and 2014.
- In the area of management (the Neelum, Lower Jhelum, Kunhar, and Poonch basins), forests and scrubs have decreased, while barren land and urban area have increased. Grasses and sparse vegetation area have remained about the same.
- Land-cover classes in the basin include forests and scrubs, grasses and sparse vegetation, orchards, cultivated cropland, urban areas, bare land, waterbodies, and snow and ice. Analysis of changes in land cover for this study showed that forests and scrubs were the most dominating feature in 1993, but bare land overtook them by 2014. Forests and scrubs decreased by 6.6 percent, while bare land increased by 8.6 percent during this period. In the area of management, forests and scrubs have decreased while bare land and urban area have increased. The areas of grasses and sparse vegetation have remained similar.

Table 2: Description of Land-Cover Classes

No.	Land-cover class	Description
1	Forest and scrubs	Contains coniferous and broadleaf forests and scrubs (thick and sparse)
2	Grasses and sparse vegetation	Contains grasses, shrubs, herbs, and very sparse vegetation
3	Orchards	Contains orchards (fruit trees)
4	Cultivated cropland	Contains those areas of cropland that were cultivated at the time of imaging
5	Urban areas	Contains urban areas and large settlements
6	Bare land	Contains bare land (including fallow agriculture land) and bare rocks
7	Waterbodies	Contains rivers, nullahs (tributaries), streams, lakes, ponds, and other water reservoirs
8	Snow and ice	Contains snow, ice, and ice-caps

The changes in land-cover classes are interlinked. For example, a reduction in forests and scrubs signifies deforestation and a corresponding increase in bare land. However, fallow land—left uncultivated in a particular season—will be detected as bare land in a satellite image. Such land may later be cultivated, while cultivated land may also be left idle. Therefore, a decrease in irrigated cropland observed in 2014 does not necessarily mean a decrease in agricultural activities: it is simply the land-cover feature or habitat observed in that month (June 2014). To gauge the level of agricultural activities more accurately, it is necessary to monitor monthly or seasonal cultivation patterns in the basin for an entire year.

The land-cover classes of grasses and sparse vegetation are highly dependent on rainfall; thus, grasses and bare land are interchangeable from year to year depending on the level of rainfall.

2.5 Sediment Audit

An audit was conducted to assess the sediment data of the Jhelum rivers and basin geology information to determine the sediment profiles of the rivers in the area of management. The audit aimed to predict how sediment loads and patterns will change with hydropower development in the basin. Details are presented in **Annex C**, while the complete report is available in **Annex G.A of Annex G**. A brief summary of the conclusions of the study is given below.

The key findings of the sediment audit are outlined below:

- In their natural state, the main rivers in the Jhelum basins have sufficient energy to transport the material being shed by the rapidly uplifting mountainous terrain, which has resulted in deeply incised and steep valleys with limited accumulation of alluvial deposits.
- The Neelum River is the largest source of sediment in the Neelum-Jhelum Basin, contributing almost half of the sediments to the lower Jhelum River and more than a third of the sediment reporting to the Mangla Reservoir. The remaining sediments in the lower Jhelum River are contributed by the middle Jhelum and Kunhar rivers as well as the area draining to the Mahl and Azad Pattan HPP sites. The Poonch River contributes about 24 percent of the load entering the Mangla Reservoir.
- There is a poor correlation between river flow and sediment transport, which is governed more by the delivery of sediment to the rivers than by their transport capacities. Sediment inputs can vary markedly over short distances.
- May and June tend to have peak sediment transport because they coincide with a period of high erodibility of the mountain slopes.

The sediment audit provides a basin overview using existing sediment data, but information about geomorphic processes at the local scale is lacking. These localized relationships affect in-channel and riparian habitat diversity and conditions, which have a controlling influence over biodiversity and ecosystems.

3. OVERVIEW OF ECOLOGY

This section provides an overview of both the aquatic and terrestrial ecological resources reported in the area of management. The aquatic and riparian ecology will be directly affected by hydropower project construction, while the terrestrial ecological resources are likely to suffer harm from the construction of electricity transmission lines.

3.1 Aquatic Ecology

At least 54 fish species have been reported in the Jhelum-Poonch Basin upstream of the Mangla Reservoir (**section 1.7**). The species that are widely distributed in the basin include the Alwan snow trout (*Schizothorax richadsonii*), Pakistani baril (*Barilius pakistanicus*), Kashmir latia (*Crossocheilus diplochilus*), sucker head (*Garra gotyla*), flathead catfish (*Glyptothorax pectinopterus*), Bhed catfish (*Glyptothorax stocki*), Nalbant's loach (*Schistura nalbanti*), Vagra baril (*Barilius vagra*), stone loach (*Schistura alepidote*), lohachata loach (*Botia lohachata*), twin-banded loach (*Botia rostrata*), and Indian loach (*Botia birdi*). Indus garua (*Clupisoma garua*), clown catfish (*Gagata cenia*), golden mahseer (*Tor putitora*), and Gora chela (*Securicula gora*) are warm-water species found in the lower reaches of the Jhelum River up to the Mangla Reservoir, particularly in the plain areas. The cool- and cold-water species, such as the Himalayan catfish (*Glyptosternum reticulatum*), Kashmir hillstream loach (*Triplophysa kashmirensis*), Leh triplophysa loach (*Triplophysa microps*), and high-altitude loach (*Triplophysa stoliczkai*), are more common in the upper reaches of the basin.

Three fish species have restricted ranges and are endemic to the Jhelum-Poonch Basin: the Kashmir hillstream loach, Nalbant's loach, and Kashmir catfish. Five of the species are long-distance migratory fish, including the Alwan snow trout, golden mahseer, sucker head, Indus garua, and Pakistani Labeo (*Labeo dyocheilus*). They tend to migrate to the upper reaches of the basin in summers where they find cooler water (HBP 2015a).

Species of food value reported from the Jhelum River and tributaries include the Reba carp (*Cirrhinus reba*), Indus garua, Pakistani Labeo, Alwan snow trout, and golden mahseer. Some important food species are non-native or introduced, including the brown trout (*Salmo trutta fario*), rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*), and silver carp (*Hypophthalmichthys molitrix*).

3.1.1 Ecological Zones in the Area of Management

There are four important and distinct rivers in the basin, namely the Neelum, the Kunhar, the Jhelum, and the Poonch. The fish fauna of these rivers is briefly described in the following sections. The rivers have been divided into different zones based on their ecological similarities.

Fish abundance and diversity is dependent on the nature of the water habitat, water temperature, water quality, conditions of the riverbed, and climatic conditions. Thus, the physical and chemical characteristics of a waterbody have a direct relationship with the type of fish found. Based on these characteristics and the diversity of fish fauna, the rivers of the area of management can be divided into the following zones:

Zone A	The Kunhar River (Lulusar Lake to Paras Town)
Zone B	The Kunhar River (Paras Town to Muzaffarabad)
Zone C	The Neelum River (Taobat to Dudhnial)
Zone D	The Neelum River (Dudhnial to Muzaffarabad)
Zone E	The Jhelum River (Chakothi to Muzaffarabad)
Zone F	Muzaffarabad City
Zone G	The Jhelum River (Downstream Muzaffarabad to the confluence with the Mahl River)
Zone H	The Jhelum River (Confluence with the Mahl River to the Mangla Reservoir)
Zone I	The Mahl River (Nar Sher Khan to the confluence with the Jhelum River)
Zone J	The Poonch River

Socio-economic similarities have also been considered for this zone delineation.

The Mangla Reservoir was created following the operation of the Mangla Dam. Since it is not a natural waterbody, the reservoir has been excluded from the area of management.

Figure 4 shows the temperature variations and distribution of fish fauna in the rivers in the area of management. **Figure 5** shows the delineated ecological zones.

It should be noted that ecological similarities are not bound by political boundaries and the ecological zones are likely to extend into India. However, these zones are shown to begin at the Line of Control for ease of reference and because they have been excluded from the area of management.

Figure 4: Temperature Delineations and Distribution of Fish Fauna in the Jhelum-Poonch Basin

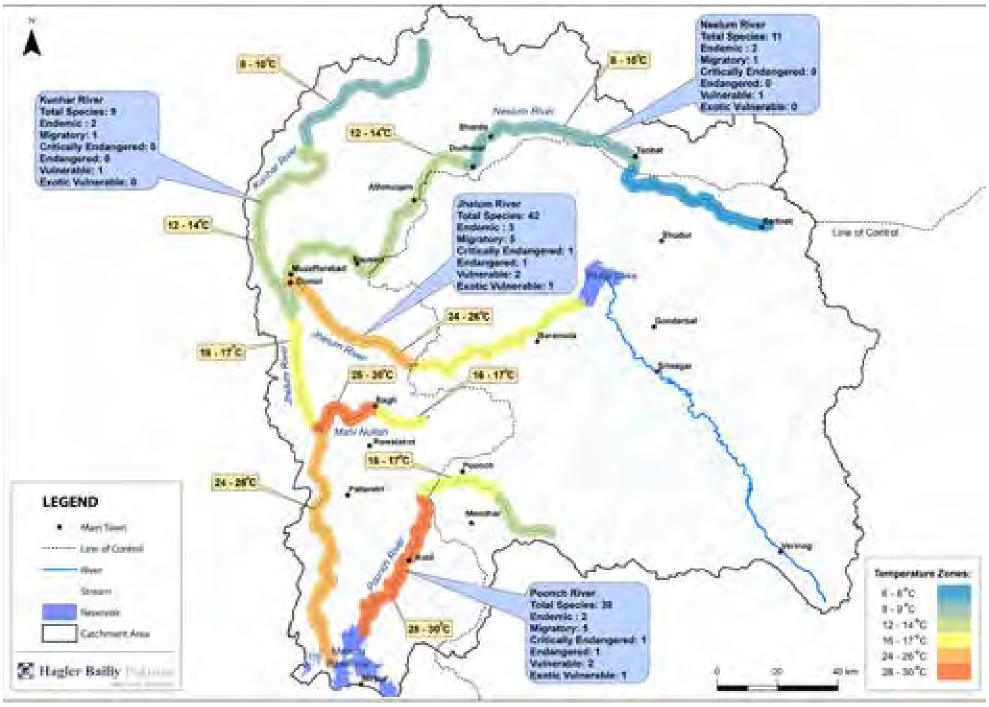
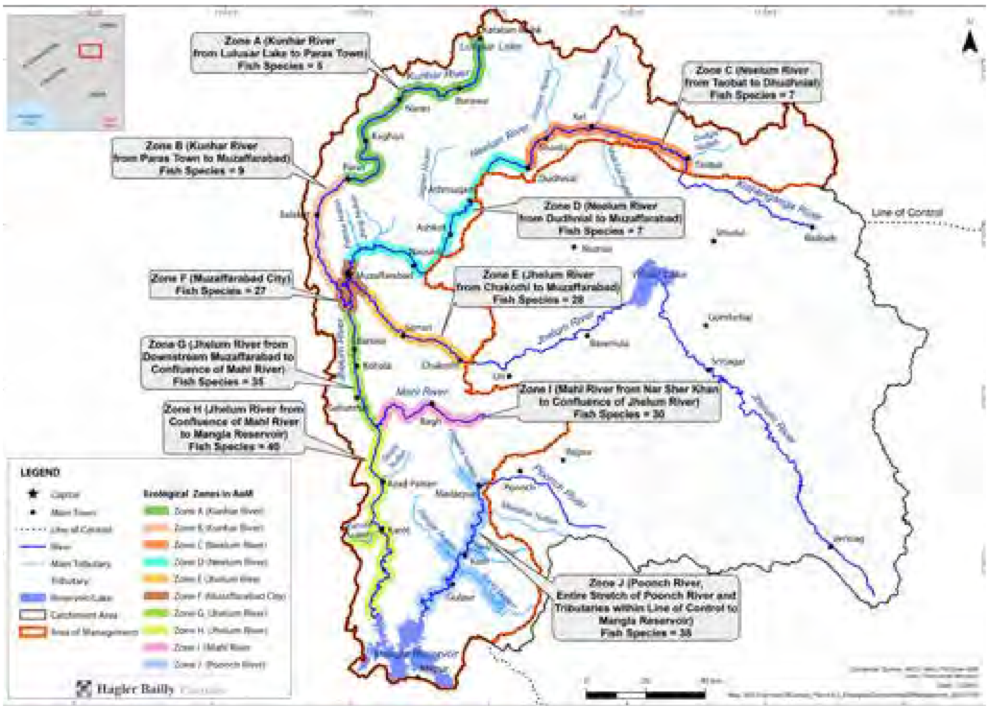


Figure 5: Ecological Zones in the Area of Management



3.1.2
Fish Species in the Area of Management

This section provides an overview of the fish species reported from the area of management, namely the Neelum, Kunhar, Jhelum, and Poonch rivers. Information for this section has been compiled through a literature review of scientific journals, websites, and ESIA reports outlined in **section 1.7**. In addition, field surveys have been conducted in river reaches where data was scarce or missing, such as in Zone C (the Neelum River—Taobat to Dudhnial).

A complete list of fish species of the Jhelum-Poonch Basin is provided in Annex D.A of **Annex D**.

The Kunhar River

Nine species have been reported from the Kunhar River, including the Alwan snow trout, a long-distance migratory fish species, and two species endemic to the basin, Nalbant's loach and the Kashmir hillstream loach. The river is further subdivided into two zones, A and B.

The common fish species in Zone A of the Kunhar River include the Alwan snow trout and rainbow trout. Two introduced, cold-water species of high food value—the brown trout and rainbow trout—are found exclusively in Zone A. There is an extensive raceway[6] culture of rainbow trout in Zone A. The Alwan snow trout and Kunar snow trout are two other species of food value, but they are caught from the river and tributaries rather than cultured.

Common species of Zone B include the Alwan snow trout, Kashmir hillstream loach, stone barb, Arif's loach (*Schistura arifi*), flathead catfish, Himalayan catfish, and Nalbant's loach.

The Neelum River

At least 11 fish species have been reported from the Neelum River. These include the high-altitude loach, Kashmir hillstream loach, Leh Triplophysa loach, Tibetan snow trout (*Diptychus maculatus*), brown trout, Alwan snow trout, and Himalayan catfish.

The Alwan snow trout is the most common fish of the Neelum River and is distributed throughout its length. The Kashmir hillstream loach is also an abundant species of the river. It is common throughout the Neelum River but with a discontinuous distribution, as it prefers a specific microhabitat of loose stones with mild water velocity. Similarly, the Himalayan catfish is found throughout the Neelum River but with a discontinuous distribution. It is the only cold-water catfish of Pakistan.

The Neelum River is further subdivided into two zones, C and D. The high-altitude loach, Leh Triplophysa loach, and Kashmir hillstream loach have been mainly reported from the upper river reaches (Zone C) and serve as food for brown trout—an introduced species that has adapted well to local conditions in the river. The other species of Zone C include the Tibetan snow trout, the Himalayan catfish, and the migratory Alwan snow trout. The temperatures in the lower reaches of the Neelum River (Zone D) are slightly higher; species like Bhed catfish, flathead catfish, Nalbant's loach, and Arif's loach prefer slightly warmer temperatures and have been recorded from this zone.

The Jhelum River

At least 42 fish species have been reported from the Jhelum River upstream and downstream of its confluence with the Neelum River (near the town of Muzaffarabad). Other common fish species of the river include Sattar's snow trout, Chirruh snow trout, Kunar snow trout, Nalbant's loach, Kashmir hillstream loach, Bhed catfish, flathead catfish, Pakistani baril, Himalayan catfish, Kashmir latia, ticto barb (*Puntius ticto*), spotfin swamp barb (*Puntius sophore*), Pakistani Labeo, Reba carp, sucker head, and Indus garua.

The species Alwan snow trout, Pakistani baril, Kashmir latia, ticto barb, sucker head, flathead catfish, Bhed catfish, and Nalbant's loach are widely distributed in the Jhelum River both upstream and downstream of its confluence with the Neelum River. The species Kashmir catfish and Himalayan catfish are mainly found in the Jhelum River upstream of Domel (Zone E) but have also been recorded in a few places downstream (Zone F and G).

The species Lohachata loach, mottled loach, and Kunar snow trout are mostly found in the lower Jhelum River (Zone G) downstream of the confluence with the Neelum River. The species Indus garua, clown catfish, and Gora chela are warm-water species and have been reported in lower reaches of the Jhelum River up to the Mangla Reservoir and even lower in the plain areas (Zone G and H). The golden mahseer is a common fish in the lower reaches of the river (Zone H) up to the Mangla Reservoir.

The Mahl River (Zone I) is an ecologically rich tributary of the Jhelum River and provides habitat for several fish species including the golden mahseer, Alwan snow trout, Kashmir latia, sucker head, Himalayan catfish, and Nalbant's loach.

[6] A raceway is an artificial channel used in aquaculture to culture aquatic organisms. It is based on continuous water flowing through the culture tanks.

The Poonch River

The Poonch River (Zone J) is a warm-water river with water temperature approaching 30°C during the summer. At least 38 fish species have been recorded from the Poonch River (Rafique 2012; HBP 2013). The diversity is higher in the area where the Poonch River meets the Mangla Reservoir.

Fish species reported from Zone J include the Pakistani baril, Punjab loach, Reba carp, Pakistani Labeo, golden mahseer, Alwan snow trout, common carp, twin-banded loach, Indus garua, Gora chela, sucker head, butter catfish, Naziri catfish, Kashmir catfish, and spiny eel. Some of these fish are long-distance migratory species, such as the mahseer and Alwan snow trout. The golden mahseer is listed as Endangered in the IUCN Red List of Threatened Species,[7] while the Kashmir Catfish is listed as Critically Endangered.

Due to the presence of fish species of conservation importance, the entire stretch of the Poonch River and its tributaries were declared the River Poonch Mahseer National Park in a letter from the AJK Secretariat Forest, Azad Kashmir Logging and Sawmills Corp. (AKLASC), and Fisheries.[8]

3.1.3 Fish Species of Concern

Species of concern in the area of management include those that are:

- Listed as Critically Endangered, Endangered, or Vulnerable in the IUCN Red List of Threatened Species
- Species that are long-distance migrants
- Species that have restricted ranges and are endemic to the Jhelum-Poonch Basin
- Edible fish species used by the communities for food and subsistence fishing, or those with high commercial importance

Non-native or introduced fish species are not considered species of concern.

Several species reported from the area of management are included in the IUCN Red List of Threatened Species. The Alwan snow trout and twin-banded loach (*Botia rostrata*) are listed as Vulnerable, the butter catfish (*Ompok bimaculatus*) is listed as Near Threatened, the golden mahseer is listed as Endangered, and the Kashmir catfish is listed as Critically Endangered. Two non-native or introduced fish species included in the IUCN Red List are the common carp (listed as Vulnerable) and the silver carp (Near Threatened). They are not considered species of concern.

Species that have restricted range and are endemic to the Jhelum-Poonch Basin include the Kashmir catfish, Nalbant's loach, and the Kashmir hillstream loach.

The long-distance migratory species reported from the area of management are the Alwan snow trout, golden mahseer, sucker head, Indus garua, and Pakistani Labeo.

Species of medium-to-high commercial value as food include the Indus garua, Chirruh snow trout, Pakistani Labeo, Alwan snow trout, and golden mahseer. Although trout species, such as the brown trout, and carp species, such as silver carp, grass carp, and common carp have food value, they are introduced species and are not considered species of concern or conservation importance.

Snow trout species such as the Chirruh snow trout, Kunar snow trout, Macropogon snow trout, and Sattar's snow trout are not widely distributed and remain restricted to specific river zones. Where they occur, however, they are caught for both food and subsistence and commercial fishing.

A list of species of concern in the area of management is shown in **Table 3**.

[7] The IUCN Red List of Threatened Species™ provides taxonomic, conservation status, and distribution information on plants and animals that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of extinction, and the main purpose of the IUCN Red List is to catalogue and highlight those plants and animals that are facing a higher risk of global extinction (that is, those listed as Critically Endangered, Endangered, and Vulnerable). The IUCN Red List also includes information on plants and animals that are categorized as Extinct or Extinct in the Wild; on taxa that cannot be evaluated because of insufficient information (Data Deficient); and on plants and animals that are either close to meeting the threatened threshold or that would be threatened were it not for an ongoing taxon-specific conservation program (Near Threatened).

[8] Government of the State of Azad Jammu and Kashmir, Secretariat Forest/AKLASC/Fisheries, Official Letter for Notification of River Poonch and Tributaries as Protected Area, 15 December 2010, Ref no: SF/AV 11358-7/2010

Table 3: List of Species of Special Concern in the Area of Management

No.	Common name	Scientific name	IUCN status	Endemic/ restricted range	Occurrence	Migratory	Commercial importance
1.	Kashmir Catfish	*Glyptothorax kashmirensis*	Critically Endangered	✓	Jhelum River Poonch River		Medium
2.	Kashmir hillstream loach	*Triplophysa kashmirensis*	Not Assessed	✓	Kunhar River Jhelum River Neelum River		Low
3.	Nalbant's loach	*Schistura nalbanti*	Not Assessed	✓	Neelum River Kunhar River Jhelum River Poonch River		Low
4.	Golden mahseer	*Tor putitora*	Endangered		Jhelum River Poonch River	✓	**High**
5.	Alwan snow trout	*Schizothorax richardsonii*	Vulnerable		Neelum River Kunhar River Jhelum River Poonch River	✓	**High**
6.	Pakistani Labeo	*Labeo dyocheilus*	Least Concern		Jhelum River Poonch River	✓	**High**
7.	Indus garua	*Clupisoma garua*	Least Concern		Jhelum River Poonch River	✓	**High**
8.	Sucker head	*Garra gotyla*	Least Concern		Jhelum River Poonch River	✓	Low
9.	Twin-banded loach	*Botia rostrate*	Vulnerable		Jhelum River Poonch River		Low
10.	Chirruh snow trout	*Schizopyge esocinus*	Not Assessed		Jhelum River Poonch River		**High**
11.	Tibetan snow trout	*Diptychus maculatus*	Not Assessed		Jhelum River Poonch River		**High**
12.	Macropogon snow trout	*Schizothorax macropogon*	Not Assessed		Jhelum River Poonch River		**High**
13.	Sattar's snow trout	*Schizothorax curvifrons*	Not Assessed		Jhelum River Poonch River		**High**
14.	Kunar snow trout	*Schizothorax labiatus*	Not Assessed		Jhelum River Poonch River		**High**

3.1.4 Ecological Importance of Zones

The different river zones identified in **section 3.1.1** vary in their sensitivity to hydropower development. The sensitivity is assessed using the same methodology outlined in the *Strategic Environmental Assessment (SEA) of Hydropower Development in Azad Jammu and Kashmir* (Annandale and HBP 2014). The ecological importance of each zone is assessed using the following indicators:

- *Fish diversity*. This refers to the type and number of fish species reported. Greater fish diversity is indicative of conditions conducive for fish feeding, breeding, and growth (Rafique 2007).
- *Conservation status*. Includes species listed in the IUCN Red List or those that are endemic to the Jhelum-Poonch Basin.[9]
- *Status as protected area*. A protected area is a clearly defined geographical space recognized, dedicated, and managed through legal or other effective means to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley 2008). Protected areas include wildlife sanctuaries and national parks declared by the local government as well as areas declared by IUCN protected areas management[10] and those containing a critical habitat as designated by IFC Performance Standards.[11]

[9] Endemism is the ecological state of being unique to a defined geographic location, such as an island, a country, a defined zone, or a habitat type.

[10] IUCN protected area management categories classify such areas according to their management objectives. The categories are recognized by international bodies such as the United Nations and by many national governments as the global standard for defining and recording protected areas. As such, the categories are increasingly being incorporated into government legislation. Available at the official website of IUCN: http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/

[11] IFC Performance Standard 6—Biodiversity Conservation and Sustainable Management of Living Natural Resources (2012): https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/policies-standards/performance-standards/ps6

- *Economic value of fish*. Fishing not only provides food for local consumption but is also a source of livelihood for individuals working in commercial fishing and the food industry, such as processing and packaging edible fish species. Fish are also important for recreational and sport fishing and tourism.
- The complete methodology for assessing the ecological importance of each zone and their sensitivity to hydropower development is given in **Annex D**.

3.1.5 Sensitivity Assessment of Zones

Each ecological zone's sensitivity to the construction and operation of HPPs has been classified into one of three categories: "highly sensitive," "moderately sensitive," and "least sensitive." These rankings are based on the Total Biodiversity Assessment Score calculated as explained below. Details are provided in **Annex D**.

Total Biodiversity Assessment Score

Three fish-related indicators—fish diversity, economic importance of fish, and conservation importance of fish—are given a score of 1, 2, and 3 depending on their rating of low, medium, and high, respectively. If the entire zone is a protected area, it is given a score of 3; if part of the zone is included in a protected area, it is given a score of 2; for a proposed protected area, the score is 1; and for no protected area present in the zone, a score of 0 is assigned. The Total Biodiversity Assessment Score for each zone is calculated by adding the scores for each of the four indicators and the following criteria to determine the zone's sensitivity to hydropower development.

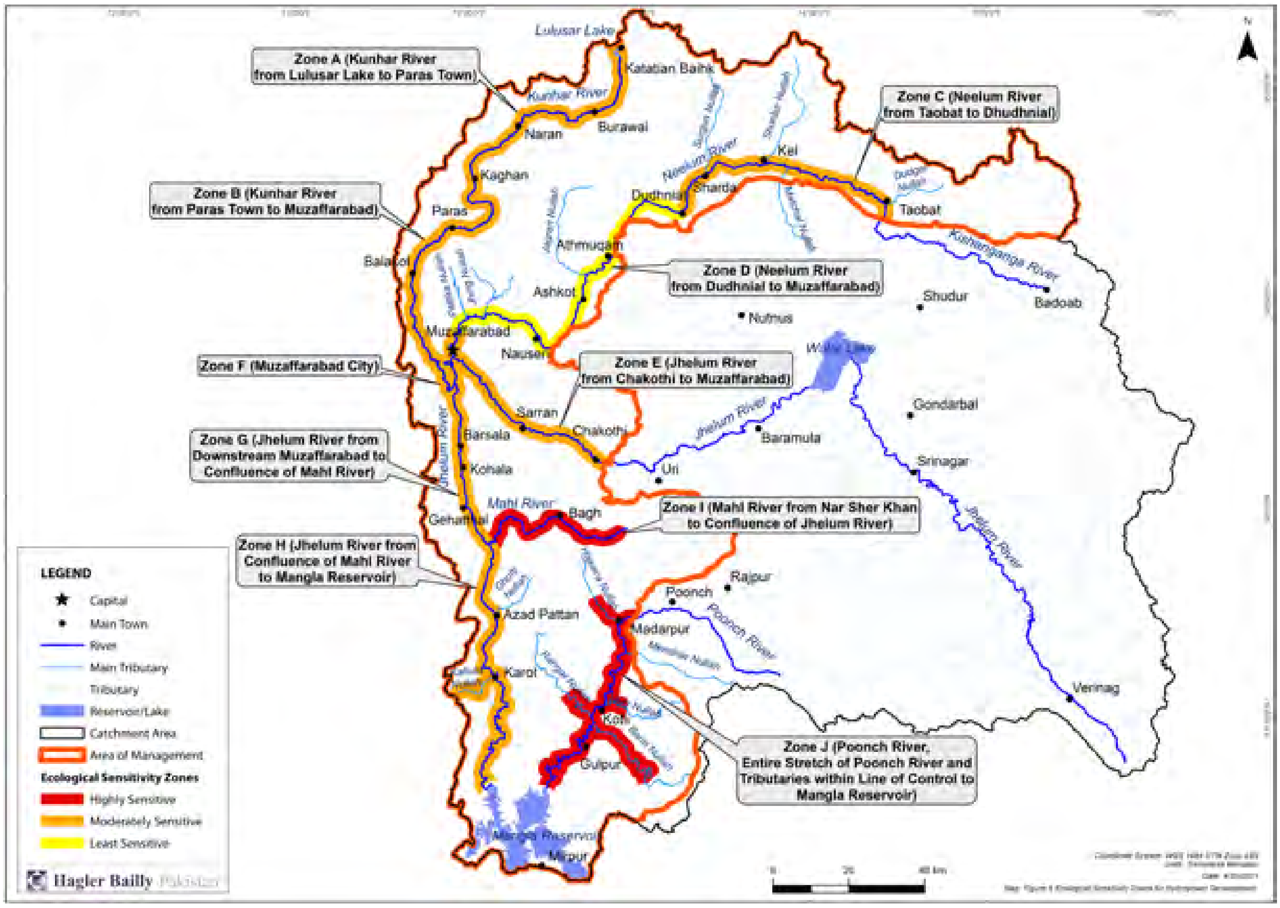
- **Least sensitivity zone**
  Total Assessment Score of 1–4
- **Moderate sensitivity zone**
  Total Assessment Score of 5–8
- **High sensitivity zone**
  Total Assessment Score of 9–12

The sensitivity rating of each designated river zone to hydropower development is shown in **Table 4** and a map of this sensitivity zoning is shown in **Figure 6**.

Table 4: Ecological Sensitivity Zoning for Hydropower Development

Zone	Ecological zone	Fish diversity	Economic importance of fish	Conservation importance of fish	Protected area	Biodiversity assessment score	Sensitivity classification
Zone A	Kunhar River (Lulusar Lake to Paras Town)	Low (1)	Medium (2)	Low (1)	Parts of Zone A included in the Lulusar-Dudipatsar National Park (2)	6	Moderate
Zone B	Kunhar River (Paras Town to Muzaffarabad)	Low (1)	Medium (2)	Medium (2)	No (0)	5	Moderate
Zone C	Neelum River (Taobat to Dudhnial)	Low (1)	Medium (2)	Medium (2)	Parts of Zone C included in Musk Deer National Park (2)	7	Moderate
Zone D	Neelum River (Dudhnial to Muzaffarabad)	Low (1)	Low (1)	Medium (2)	No (0)	4	Least
Zone E	Jhelum River (Chakothi to Muzaffarabad)	High (3)	Medium (2)	High (3)	No (0)	8	Moderate
Zone F	Muzaffarabad City	High (3)	Medium (2)	High (3)	No (0)	8	Moderate
Zone G	Jhelum River (Downstream Muzaffarabad to the confluence with the Mahl River)	High (3)	Medium (2)	High (3)	No (0)	8	Moderate
Zone H	Jhelum River (Confluence of the Mahl River with the Mangla Reservoir)	High (3)	Medium (2)	Medium (2)	No (0)	7	Moderate
Zone I	Mahl River (from Nar Sher Khan to the confluence with the Jhelum River)	High (3)	Medium (2)	High (3)	Proposed as protected area (1)	9	High
Zone J	Poonch River	High (3)	High (3)	High (3)	National park (3)	12	High

Figure 6: Ecological Sensitivity Zones for Hydropower Development



Discussion

As shown in **Table 4**, only two designated river zones have been categorized as "highly sensitive": Zone I (the Mahl River) and Zone J (the Poonch River and its tributaries).

"Moderately sensitive" zones include Zone A (the Kunhar River from Lulusar Lake to Paras Town), Zone B (the Kunhar River from Paras Town to Muzaffarabad), Zone C (the Neelum River from Taobat to Dudhnial), Zone E (the Jhelum River from Chakothi to Muzaffarabad), Zone F (Muzaffarabad City), Zone G (Downstream of the Jhelum River from Muzaffarabad to the confluence with the Mahl River) and Zone H (the Jhelum River from the confluence with the Mahl River to the Mangla Reservoir).

Only Zone D (the Neelum River from Dudhnial to Muzaffarabad) has been categorized as "least sensitive." The reasons for these categorizations are discussed below.

Highly Sensitive Zone

The salient features of Zone I and Zone J justifying their designation as "highly sensitive" are outlined below:

Zone I (the Mahl River)

- High fish diversity of 30 fish species
- High conservation importance for fish since the zone forms a breeding habitat for the Endangered fish species, the golden mahseer
- Presence of Vulnerable fish species: twin-banded loach and the Alwan snow trout
- Presence of endemic fish species, Nalbant's loach
- Presence of economically important fish species, including the golden mahseer, Alwan snow trout, Pakistani Labeo, spiny eel, and sucker head
- The AJK Fisheries and Wildlife Department has proposed declaring the entire length of the Mahl River as a protected area; the official notification is, however, pending.

Zone J (the Poonch River and Its Tributaries)

- High fish diversity of 38 species in a stretch of about 100 km
- Presence of six species on the IUCN Red List: the Kashmir catfish (Critically Endangered),

golden mahseer (Endangered), Alwan snow trout (Vulnerable), common carp (Vulnerable), twin-banded loach (Vulnerable), and butter catfish (Near Threatened)

- Presence of endemic fish species, including Nalbant's loach and the Kashmir catfish
- Presence of five long-distance migratory fish species: the golden mahseer, Alwan snow trout, Pakistani Labeo, Indus garua, and sucker head
- Presence of economically important fish species, such as the golden mahseer, Alwan snow trout, Chirruh snow trout, common carp, grass carp, Pakistani Labeo, butter catfish, sucker head, Indus garua, and spiny eel
- The entire Poonch River and its tributaries have been declared the River Poonch Mahseer National Park.

Moderately Sensitive Zone

The seven "moderately sensitive" zones are Zone A, Zone B, Zone C, Zone E, Zone F, Zone G, and Zone H. The reasons for the categorization of each zone are discussed below.

Zone A (the Kunhar River from Lulusar Lake to Paras Town)

- Only five reported species, showing low fish diversity
- The only fish species of conservation importance found in this zone: the Alwan snow trout
- The Kashmir hillstream loach found in this zone has restricted range and is endemic to the Jhelum-Poonch Basin; however, its population in this zone is low
- Three of the fish species reported from this zone are economically important: the brown trout and rainbow trout have high commercial value, while the Alwan snow trout is locally consumed as food
- Some parts of this zone are included in the Lulusar-Dudipatsar National Park, a protected area.

Zone B (the Kunhar River from Paras Town to Muzaffarabad)

- Low fish diversity of nine fish species
- No Endangered or Critically Endangered fish species
- Presence of endemic fish species, including Nalbant's loach and the Kashmir hillstream loach
- The Alwan snow trout is the only long-distance migratory fish species in this zone
- Two of the fish species reported from this zone are economically important: the rainbow trout has high commercial value and the Alwan snow trout is also locally consumed as food.

Zone C (the Neelum River from Taobat to Dudhnial)

- Low fish diversity of seven fish species
- The Alwan snow trout, the only long-distance migratory fish species found in the zone, is listed as Vulnerable in the IUCN Red List. However, no Endangered or Critically Endangered fish species has been reported from this zone
- The Kashmir hillstream loach, a restricted-range species endemic to the Jhelum-Poonch Basin, is abundant in this zone
- Three of the fish species reported from this zone are economically important: the brown trout has high commercial value, while the Alwan snow trout and Tibetan snow trout are locally consumed as food
- Some parts of this zone are included in the Musk Deer National Park, a protected area.

Zone E (the Jhelum River from Chakothi to Muzaffarabad)

- High fish diversity of 28 fish species
- The Kashmir catfish recorded from this zone is listed as Critically Endangered in the IUCN Red List 2018, while the Alwan snow trout is listed as Vulnerable
- The Kashmir hillstream loach, Kashmir catfish, and Nalbant's loach reported from this zone are restricted-range species and endemic to the Jhelum-Poonch Basin
- This zone provides an important habitat for the Kashmir catfish and the largest global population of this species is found in this zone
- The four migratory species reported from this zone are the Alwan snow trout, Pakistani Labeo, Indus garua, and sucker head
- Commercially important fish species found in this zone include the Alwan snow trout, Indus garua, Pakistani Labeo, Sattar's snow trout, Kunar snow trout, sucker head, and Chirruh snow trout.

Zone F (Muzaffarabad City)

- High fish diversity of 27 fish species
- Two fish species of conservation importance reported from this zone are the Kashmir catfish (listed as Critically Endangered in the IUCN

Red List) and the Alwan snow trout (listed as Vulnerable)

- Two restricted-range species, Nalbant's loach and the Kashmir hillstream loach, are found in this zone
- Four long-distance migratory fish species reported from this zone are the Alwan snow trout, Pakistani Labeo, Indus garua, and sucker head
- Commercially important fish species reported from this zone include the Alwan snow trout, Indus garua, Pakistani Labeo, Sattar's snow trout, Kunar snow trout, common carp, and Chirruh snow trout.

Zone G (Downstream of the Jhelum River from Muzaffarabad to the confluence with the Mahl River)

- High fish diversity of 35 fish species
- Four fish species reported from this zone are listed in the IUCN Red List 2018: the Kashmir catfish (Critically Endangered), golden mahseer (Endangered), Alwan snow trout (Vulnerable), and twin-banded loach (Vulnerable)
- Three fish species that have restricted range and are endemic to the Jhelum-Poonch Basin reported from this zone are the Kashmir hillstream loach, Nalbant's loach, and Kashmir catfish
- Five long-distance migratory species reported from this zone are the golden mahseer, Alwan snow trout, Pakistani Labeo, Indus garua, and sucker head
- Commercially important fish species reported from this zone include the golden mahseer, Alwan snow trout, Pakistan Labeo, Indus garua, and Macropogon snow trout.

Zone H (the Jhelum River from the confluence with the Mahl River to the Mangla Reservoir)

- High fish diversity shown by 40 reported species
- Three fish species of conservation importance reported from this zone are the golden mahseer (Endangered), Alwan snow trout (Vulnerable), and twin-banded loach (Vulnerable)
- Nalbant's loach is the only restricted range and endemic fish species reported from this zone
- The commercially important fish fauna of this zone includes the golden mahseer, Pakistani Labeo, Indus garua, and Alwan snow trout.

Least Sensitive Zone

Only one zone has been categorized as "least sensitive" to hydropower development because of its low ecological importance.

Zone D (the Neelum River from Dudhnial to Muzaffarabad)

- Low fish diversity shown by seven reported species
- The Alwan snow trout reported from this zone is listed as Vulnerable in the IUCN Red List. However, no Endangered or Critically Endangered fish species has been reported from this zone
- The Kashmir hillstream loach and Nalbant's loach reported from this zone have restricted ranges and are endemic to the Jhelum-Poonch Basin
- The Alwan snow trout is the only long-distance migratory fish and economically important species in this zone.

The sensitivity zoning outlined above has been revised from the categorization given in the SEA of Hydropower Development in AJK (IUCN Pakistan 2014), as knowledge about the aquatic biodiversity of the rivers and the fish fauna of each zone has increased over the last few years. Apart from Zone D (Neelum River from Dudhnial to Muzaffarabad), other zones previously categorized as "least sensitive" in the SEA have been reclassified as "moderately sensitive." In addition to Zone J (the Poonch River), Zone I (the Mahl River) has also now been categorized as "highly sensitive."

Conclusions

Broadly speaking, the impact of HPPs on ecosystems is greater for aquatic ecology than for terrestrial flora and fauna. Even though the construction of the powerhouse and associated structures takes place on riverbanks, the proportion of habitat destroyed is small in relation to the landscape, particularly for run-of-the-river HPPs, which do not have large storage capacity.

River-dependent flora (such as riparian vegetation), water birds (such as ducks and geese), and river mammals (such as otters) are more likely to suffer negative consequences from flow variations caused by HPP operation, though birds are sensitive to disturbance and tend to avoid such areas. The most significant ecological impact, however, is likely to be on the aquatic ecological resources including the algal flora, macroinvertebrates, and fish. Main concerns regarding the impact of HPPs on river flora and fauna are outlined below:

- Species of conservation importance (those that are in the IUCN Red List or endemic to the Jhelum-Poonch Basin) should be protected from population decline. These include the fish species and the river-dependent mammals such as otters.

- Fish of economic importance—those caught for recreational fishing, those that serve as food for local communities, and species of high commercial value—should be protected from decline as the communities are socially and economically dependent on these fish.
- The aquatic ecosystem integrity should be maintained. Any natural or critical habitat should be identified and protected.
- Different river segments in the area of management vary in their ecological importance and sensitivity to hydropower development. The management and protection approach needs to consider these different sensitivities during the design and operation of HPPs.

Recommendations for managing and minimizing the negative impacts of HPPs on aquatic biodiversity are discussed in **sections** 7 and 8.

3.2 Terrestrial Ecology

This section provides an overview of the terrestrial ecological resources in the area of management, including the three provinces straddling the Jhelum-Poonch Basin, namely Azad Jammu and Kashmir, Khyber Pakhtunkhwa, and Punjab.

3.2.1 Overview

Azad Jammu and Kashmir

Terrestrial Flora

Azad Jammu and Kashmir (AJK) falls into the Sino-Japanese group and has very rich floral diversity comprising evergreen coniferous forest, subtropical thorny forest, and deciduous trees forest. With its good climate, AJK provides habitat for 10.6 percent of the total flora of Pakistan (Ali and Qaiser 1986). Floristically, there are three main ecozones in AJK: subtropical forest and a mix of subtropical thorn forest and deciduous forest. The dominant plant species found in these forests (Nasir, Ali, and Stewart 1972) include deodar (*Cedrus deodara*), pine (*Pinus wallichiana*), spruce (*Picea smithiana*), fir (*Abies pindrow*), chilgoza pine (*Pinus gerardiana*), juniper (*Juniperus macropoda*), evergreen oak (*Quercus ilex*), pine (*Pinus roxburghii*), oak (*Quercus incana*), Indian lycium (*Berberis lyceum*), common barberry (*Berberis heteropoda*), and granda (*Carissa oppaca*).

Mammals

Some common mammal species reported from AJK (HBP 2011; Ahmad et al. 2016) include common leopard (*Panthera pardus*), snow leopard (*Panthera uncia*), gray wolf (*Canis lupus*), Asiatic black bear (*Ursus thibetanus*), brown bear (*Ursus arctos*), Indian pangolin (*Manis crassicaudata*), musk deer (*Moschus chrysogaster*), gray goral (*Naemorhedus goral*), gray langur (*Semnopithecus ajax*), long-tailed marmot (*Marmota caudate*), and giant red flying squirrel (*Petaurista petaurist*).

Avifauna

A total of 442 bird species have been reported from AJK.[12] These include members of the family Phasianidae, Anatidae, Podicipedidae, Ardeidae, Falconidae, Accipitridae, Cuculidae, Strigidae, Corvidae. Most of the bird species are resident. However, some migratory bird species have also been reported from AJK (Khan and Ali 2015; Umar et al. 2018). During the migration period, about 15 species of ducks and geese visit different parts of AJK. According to Khan and Ali (2015) and Khalique et al. (2012), these include common teal (*Anas crecca*), common pochard (*Aythya ferina*), mallard (*Anas platyrhynchos*), northern pintail (*Anas acuta*), Eurasian wigeon (*Anas penelope*), white-eyed pochard (*Aythya nyroca*), common shelduck (*Tadorna tadorna*), ruddy shelduck (*Tadorna ferruginea*), and bar-headed goose (*Anser indicus*).

Herpetofauna

AJK harbours a high reptilian diversity because of its unique topography (Baig 1988). There is a distinct altitudinal range and relatively high precipitation; therefore, the fauna of both northern regions and the Potwar Plateau can be found here (Khan 2006). The common herpetofauna species include the Indus Valley toad (*Bufo stomaticus*), Indian skittering frog (*Euphlyctis cyanophlyctis*), Asian common toad (*Duttaphrynus melanostictus*), red sand boa (*Eryx johnii*), Russell's viper (*Daboia russelii*), Indian krait (*Bungarus caeruleus*), Himalayan rock agama (*Laudakia himalayana*), Kashmir rock agama (*Laudakia Laudakia tuberculata*), Asian garden lizard (*Calotes versicolor*), and Bengal monitor lizard (*Varanus bengalensis*).

[12] Bird Life International website: http://avibase.bsc-eoc.org/checklist.jsp?region=PKjk&list=howardmoore

Khyber Pakhtunkhwa

Terrestrial Flora

Khyber Pakhtunkhwa (KP) lies in the Sino-Japanese phytogeographical region, which includes the Himalayas (Ali and Qaiser 1986). Floristically, this region is rich and comprises evergreen coniferous forests. According to Afza et al. (2016), the common plants species reported from KP include pine (*Pinus roxburghii*), deodar (*Cedrus deodara*), Himalayan pine (*Pinus wallichiana*), fir (*Abies pindrow*), oak (*Quercus incana*), Kamala (*Mallotus philippensis*), and Indian rosewood (*Dalbergia sissoo*).

Mammals

The key mammal species reported from this area (HBP 2015a) include the common leopard (*Panthera pardus*), snow leopard (*Panthera uncia*), Asiatic black bear (*Ursus thibetanus*), brown bear (*Ursus arctos*), yellow-throated marten (*Martes flavigula*), musk deer (*Moschus chrysogaster*), gray goral (*Naemorhedus goral*), gray langur (*Presbytis entellus*), long-tailed marmot (*Marmota caudate*), giant red flying squirrel (*Petaurista petaurista*), and Himalayan pipistrelle (*Pipistrellus javanicus*).

Avifauna

A total of 559 bird species have been reported from KP.[13] These include members of the family Anatidae, Phasianidae, Podicipedidae, Phoenicopteridae, Ciconiidae, Anhingidae, Ardeidae, and Accipitridae. Most of the bird species are resident. However, some migratory bird species have also been reported (Umar et al. 2018), including the common teal (*Anas crecca*), common pochard (*Aythya ferina*), mallard (*Anas platyrhynchos*), northern pintail (*Anas acuta*), Eurasian wigeon (*Anas penelope*), white-eyed pochard (*Aythya nyroca*), common shelduck (*Tadorna tadorna*), ruddy shelduck (*Tadorna ferruginea*), and bar-headed goose (*Anser indicus*).

Herpetofauna

About 32 herpetofauna species has been reported from different parts of KP. According to Khan (2006), the common herpetofauna species include the Indus Valley toad (*Bufo stomaticus*), Asian common toad (*Duttaphrynus melanostictus*), Indian cricket frog (*Fejervarya limnocharis*), Indian skittering frog (*Euphlyctis cyanophlyctis*), red sand boa (*Eryx johnii*), Russell's viper (*Daboia russelii*), Jan's Cliff racer (*Platyceps rhodorachis*), Himalayan rock agama (*Laudakia himalayana*), Kashmir rock agama (*Laudakia Laudakia tuberculata*), Rohtas Fort thin-toed gecko (*Cyrtopodion rohtasfortai*), Asian garden lizard (*Calotes versicolor*), and Bengal monitor lizard (*Varanus bengalensis*).

Punjab

Terrestrial Flora

The area of the Punjab province that falls within the area of management has four different kinds of forests: moist temperate forest, subtropical evergreen olive forests, subtropical pine forests, and mixed forests. Dominant plant species reported from this area include pine (*Pinus roxburghii*), wild olive (*Olea ferruginea*), Kamala (*Mallotus philippensis*), Indian rosewood (*Dalbergia sissoo*), and hop bush (*Dodonea viscosa*). Most of these plants belong to the Asteraceae, Fabaceae, Poaceae, and Rosaceae families (Ahmed et al. 2019).

Mammals

The key mammal species reported from Punjab in the area of management (HBP 2015a) include the common leopard (*Panthera pardus*), leopard cat (*Prionailurus bengalensis*), Asiatic jackal (*Canis aureus*), red fox (*Vulpes vulpes*), small Indian civet (*Viverricula indica*), common palm civet (*Paradoxurus hermaphroditus*), Asiatic small mongoose (*Herpestes javanicus*), wild boar (*Sus scrofa*), Indian porcupine (*Hystrix indica*), and Cape hare (*Lepus capensis*).

Avifauna

The common bird species reported from Punjab in the area of management belong to different families including Accipitridae, Phasianidae, Paridae, Timaliidae, Sylviidae, and Motacillidae. These include the tawny eagle (*Aquila rapax*), common kestrel (*Falco tinnunculus*), white-throated kingfisher (*Halcyon smyrnensis*), black kite (*Milvus migrans*), shikra (*Accipiter badius*), Eurasian sparrow hawk (*Accipiter nisus*), little egret (*Egretta garzetta*), cattle egret (*Bubulcus ibis*), peafowl (*Pavo cristatus*), Kalij pheasant (*Lophura leucomelanos*), Indian rock pigeon (*Columba livia*), Indian roller (*Coracias benghalensis*), and house crow (*Corvus splendens*).[14] Both resident and migratory bird species have been reported from Punjab (Ali 2005; Ali and Akhtar 2005; Umar et al. 2018).

[13] Official website of Avibase—The World Bird Database: https://avibase.bsc-eoc.org/checklist.jsp?region=PKnw&list=howardmoore

[14] Official website of Avibase—The World Bird Database Bird checklists: https://avibase.bsc-eoc.org/checklist.jsp?region=PKpb&list=howardmoore

Herpetofauna

About 32 herpetofauna species have been reported from different parts of the Punjab province. According to Khan (2006), the common herpetofauna species include the Indus Valley toad (*Bufo stomaticus*), Asian common toad (*Duttaphrynus melanostictus*), Indian cricket frog (*Fejervarya limnocharis*), Indian skittering frog (*Euphlyctis cyanophlyctis*), red sand boa (*Eryx johnii*), Russell's viper (*Daboia russelii*), checkered keelback (*Xenochrophis piscator*), Kashmir blind snake (*Typhlops diardi plattyventris*), Central Asia cobra (*Naja oxiana*), Indian rock python (*Python molusrus*), Jan's Cliff racer (*Platyceps rhodorachis*), Himalayan rock agama (*Laudakia himalayana*), Kashmir rock agama (*Laudakia Laudakia tuberculate*), Rohtas Fort thin-toed gecko (*Cyrtopodion rohtasfortai*), Asian garden lizard (*Calotes versicolor*), and Bengal monitor lizard (*Varanus bengalensis*).

3.2.2
Protected and Sensitive Areas

This section provides an overview of the protected and sensitive areas in the area of management.

Protected Areas

The Wildlife Act of the provinces empowers the provincial government to "declare any land as protected area by notification in the official gazette as may be deemed necessary to constitute such land as a protected." Human activities are prohibited or controlled in legally protected areas to safeguard the habitats of particular species. Protected area categories listed in the legislation include wildlife sanctuary, closed area, site of special scientific interest, wildlife refuge, national park, biosphere reserve, national natural heritage site, biodiversity reserve, and game reserve.

Table 5 lists the national parks, wildlife sanctuaries, and game reserves in the area of management as well as their important wildlife species. Several game reserves have been designated to conserve game animals for hunting. **Figure 7** shows the location of the existing and proposed protected areas recommended by provincial government departments.

Table 5: Ecological Resources in Protected Areas in the Area of Management

No.	Protected area	Wildlife species
Azad Jammu and Kashmir		
1	Musk Deer National Park	Snow leopard, brown bear, Asiatic black bear, gray wolf, musk deer, gray langur, wooly flying squirrel, Himalayan ibex, golden eagle, griffon vulture, monal pheasant, koklass pheasant, and chukar partridge (Anwar and Minhas 2008; Ahmad et al. 2016)
2	Ghamot National Park	Snow leopard, brown bear, Asiatic black bear, gray wolf, musk deer, gray langur, wooly flying squirrel, Himalayan ibex, griffon vulture, monal pheasant, koklass pheasant, and chukar partridge (Qamar 1996)
3	Machiara National Park	Common leopard, yellow-throated marten, Asiatic black bear, gray wolf, musk deer, gray goral, gray langur, golden eagle, griffon vulture, western tragopan, monal pheasant, koklass pheasant, chukar partridge, and kalij pheasant (Baig 2004)
4	Toli Peer National Park	Common leopard, Asiatic black bear, common palm civet, small Indian civet, gray langur, cheer pheasant, and western tragopan (Jammu 2016)
5	Poonch River Mahseer National Park	Common leopard, Indian pangolin, Asiatic jackal, small Indian civet, river otter, white-rumped vulture, Egyptian vulture, Himalayan griffon vulture, and steepe eagle (HPB 2015a; Ahmad et al. 2020)
6	Pir Lasura National Park	Common leopard, Indian pangolin, Asiatic jackal, small Indian civet, white-rumped vulture, Egyptian vulture, Himalayan griffon vulture, and steepe eagle (Manzoor et al. 2013)
7	Salkhala Game Reserve	Common leopard, gray goral, musk deer, rhesus monkey, gray langur, black bear, yellow-throated marten, palm civet, red fox, western tragopan, koklass pheasant, monal pheasant, kalij pheasant, and Himalayan griffon vulture (Awan, Ali, and Lee 2012)

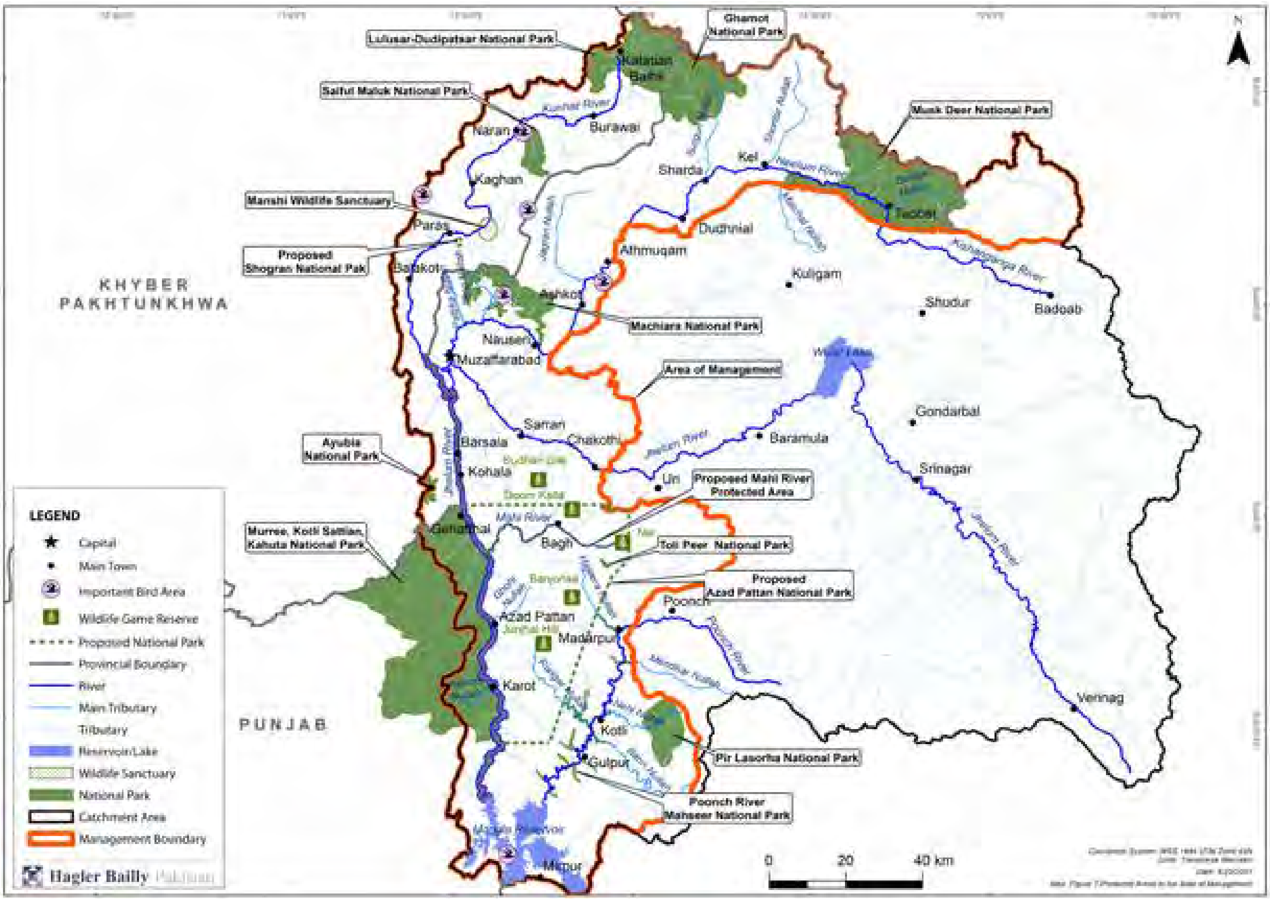
No.	Protected area	Wildlife species
8	Qazi Nag Game Reserve	Common leopard, Pir Panjal markhor, gray goral, musk deer, gray langur, black bear, yellow-throated marten, western tragopan, cheer pheasant, koklass pheasant, monal pheasant, kalij pheasant, and Himalayan griffon[15]
9	Moji Game Reserve	Common leopard, Pir Panjal markhor, gray goral, musk deer, rhesus monkey, gray langur, black bear, brown bear, yellow-throated marten, palm civet, western tragopan, koklass pheasant, monal pheasant, kalij pheasant, and Himalayan griffon (Ahmed, Awan, and Anwar 1999)
10	Hillan Game Reserve	Common leopard, Pir Panjal markhor, gray goral, musk deer, rhesus monkey, gray langur, black bear, yellow-throated marten, palm civet, western tragopan, cheer pheasant, koklass pheasant, kalij pheasant, and Himalayan griffon (Dar 2012)
11	Mori Said Ali Game Reserve	Musk deer, Himalayan ibex, gray goral, black bear, palm civet, gray langur, rhesus monkey, koklass pheasant, and western tragopan (Dar 2012)
12	Phala Game Reserve	Common leopard, Himalayan ibex, musk deer, gray goral, rhesus monkey, black bear, gray langur, yellow-throated marten, palm civet, koklass pheasant, and western tragopan (Khan et al. 2006)
13	Doom Kalla Game Reserve	Common leopard, Asiatic jackal, red fox, chukar partridge, and kalij pheasant (Saleem et al. 2018)
14	Sudhan Gali Game Reserve	Black bear, common leopard, leopard cat, Asiatic jackal, red fox, palm civet, chukar partridge, kalij pheasant, and koklass pheasant (Saleem et al. 2018)
15	Nar Game Reserve	Common leopard, leopard cat, Asiatic jackal, red fox, palm civet, chukar partridge, and kalij pheasant (Saleem et al. 2018)
16	Junjhal Hill Game Reserve	Common leopard, leopard cat, Asiatic jackal, red fox, palm civet, chukar partridge, and kalij pheasant (Saleem et al. 2018)
17	Banjosa Game Reserve	Common leopard, leopard cat, Asiatic jackal, red fox, palm civet, yellow-throated marten, chukar partridge, and kalij pheasant (Dar 2012)
Khyber Pakhtunkhwa (KP)		
1	Ayubia National Park	Asiatic black bear, common leopard, common palm civet, small Indian civet, yellow-throated marten, red fox, rhesus monkey, gray goral, monal pheasant, khalij pheasant, golden eagle, griffon vulture, honey buzzard, and peregrine falcon (Shafique and Barkati 2010)[16]
2	Saiful Muluk National Park	Snow leopard, brown bear, Himalayan ibex, long-tailed marmot, alpine weasel, Himalayan snowcock, and migratory waterfowl (Shah et al. 2013)
3	Lulusar-Dudipatsar National Park	Snow leopard, brown bear, Himalayan ibex, long-tailed marmot, alpine weasel, Himalayan snowcock, and migratory waterfowl[17]
4	Manshi Wildlife Sanctuary	Asiatic black bear, common leopard, yellow-throated marten, musk deer, gray langur, long-legged buzzard, western tragopan, monal pheasant, and koklass pheasant
Punjab		
1	Murree-Kotli Sattian-Kahuta National Park	Common leopard, Asiatic jackal, red fox, small Indian civet, Asian small mongoose (Khatoon et al. 2019)

[15] Qazi Nag Game Reserve Biodiversity Action Plan for Key Wildlife Species, the GEF Small Grants Program: https://sgp.undp.org/all-documents/country-documents/1140-bio-diversity-conservation-of-qazi-nag-game-reserve/file.html

[16] Official website of Avibase—The World Bird Database: https://avibase.bsc-eoc.org/checklist.jsp?region=PKnw&list=howardmoore

[17] Floral and Faunal Diversity Of Lulusar Dudipatsar National Park Upper Kaghan, website of Envirocivil.com: https://envirocivil.com/environment/floral-and-faunal-diversity-of-lulusar-dutipatsar-national-park-upper-kaghan/

Figure 7: Protected Areas in the Area of Management



Ecologically Sensitive Areas

The legally protected areas have been described in the previous section. This section identifies additional ecologically sensitive areas that harbor habitats, species, or ecosystems of conservation importance.

The following methodology was employed to identify "sensitive areas" in the area of management:

- Literature review of books, scientific journal articles, online reports, and ESIA reports in the area of management (**section 1.7**).
- Interviews and consultations with scientists, researchers, and government officials, including the chairman of the Department of Zoology at The University of Azad Jammu & Kashmir, the director of Himalayan Nature, a nonprofit organization, the division forest officer of Abbottabad City, and bird experts of WWF Pakistan.

Areas were categorized as "sensitive" if they met the following criterion:

- Habitats of significant importance for terrestrial species listed as Critically Endangered or Endangered in the IUCN Red List[18] or Pakistan Mammals Red List (Sheikh and Molur 2004)
- Habitats of significant importance for restricted-range species[19]
- Habitats of significant importance for migratory or congregatory species
- Areas identified as Critical Habitat according to criteria laid out in IFC Performance Standard 6 (2012)

[18] The IUCN Red List of Threatened Species. Version 2017-3: www.iucnredlist.org

[19] Restricted-range species are those with a geographically restricted area of management. IFC Performance Standard 6 defines restricted range for terrestrial vertebrates as an extent of occurrence of 50,000 km² or less.

- Areas listed as protected by international conservation organizations, including those protected by the IUCN (1994), which divides areas into categories I–VI, wetlands of international importance (according to the Ramsar Convention)[20]; important bird areas (defined by Birdlife International)[21]; and biosphere reserves under the Man and the Biosphere Programme of the United Nations Educational, Scientific and Cultural Organization (UNESCO)[22]

The ecologically sensitive areas identified in the area of management and the basis for selection are briefly described in **Table 6. Figure 8** shows the location of these sensitive areas.

Table 6: Sensitive Terrestrial Areas in the Area of Management

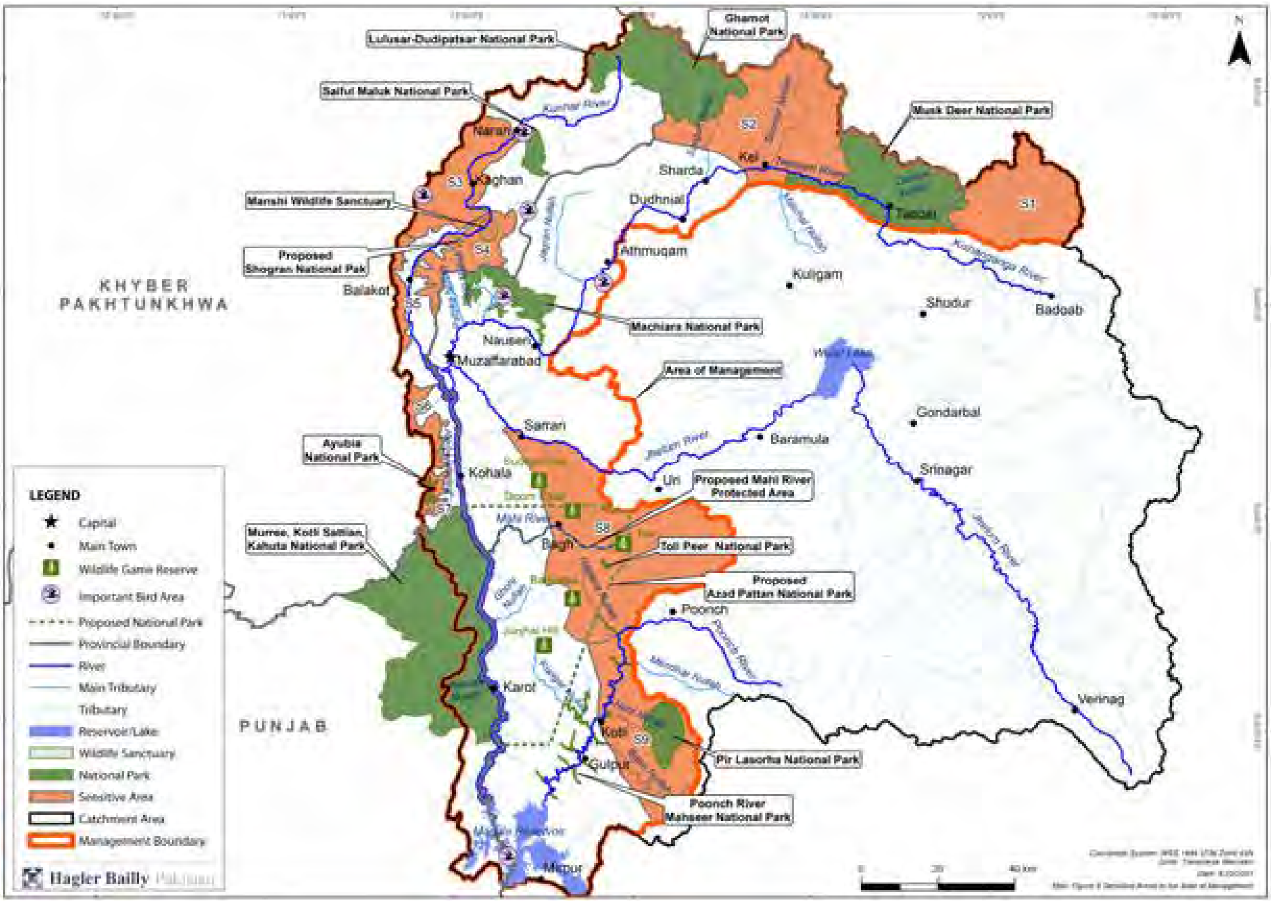
No	Sensitive area	Justification for selection
Azad Jammu and Kashmir		
1.	S1	The well-managed Musk Deer National Park is in the vicinity of S1. The area has undisturbed and quality habitat with the presence of globally threatened wildlife. Endangered mammal species, such as the musk deer, gray langur, and wooly flying squirrel, are reported. Other wildlife species of conservation importance include the snow leopard, Asiatic black bear, brown bear, gray wolf, western tragopan, and griffon vulture.
2.	S2	The well-managed Ghamot National Park is in the vicinity of S2, with undisturbed and quality habitats and the presence of globally threatened wildlife species. Endangered mammalian species, such as the musk deer, gray langur, and wooly flying squirrel, have been reported from S2. Other wildlife species of conservation importance include the snow leopard, Asiatic black bear, brown bear, gray wolf, western tragopan, and griffon vulture.
3.	S3	Thick and undisturbed coniferous forest is found in this area. The Saiful Muluk National Park, proposed Shogran National Park, and Manshi Wildlife Sanctuary are close to this area. Important wildlife species reported from S3 include the musk deer, gray langur, common leopard, Asiatic black bear, yellow-throated marten, long-tailed marmot, griffon vulture, western tragopan, and migratory waterfowl (ducks, geese, and grebes).
4.	S4	This area is on the border of the Machiara National Park and includes the Manshi Wildlife Sanctuary and proposed Shogran National Park. Most of the habitats found in the S4 are coniferous forest and house important wildlife species. The threatened wildlife species reported from S4 include the musk deer, gray langur, Asiatic black bear, common leopard, gray goral, and migratory waterfowl (ducks, geese, and grebes).
5.	S5	Important wildlife species reported from this area include the musk deer, Asiatic black bear, common leopard, gray goral, western tragopan, and migratory waterfowl (ducks, geese, and grebes).
6.	S6	This area has thick and undisturbed coniferous forest. Important wildlife species reported from S6 include the common leopard, Asiatic black bear, musk deer, gray goral, western tragopan, and migratory waterfowl (ducks, geese, and grebes).
7.	S7	This area is in the vicinity of the Ayubia National Park and has coniferous forest that provides quality habitats for several wildlife species, including the common leopard, Asiatic black bear, gray goral, common palm civet, and griffon vulture.
8.	S8	This area includes the Toli Peer National Park and several wildlife game reserves. Most of the habitats consist of relatively undisturbed coniferous forest that house several globally and nationally threatened wildlife species. These include the musk deer, gray langur, common leopard, Asiatic black bear, Asiatic jackal, red fox, steepe eagle, western tragopan, and cheer pheasant.
9.	S9	This area includes two protected areas: the Poonch River Mahseer National Park and Pir Lasura National Park. Threatened species reported from this area include the pangolin, river otter, common leopard, white-rumped vulture, Egyptian vulture, and steepe eagle.

[20] The Ramsar Convention, or the Convention on Wetlands of International Importance (Ramsar sites), administered by the Ramsar Secretariat, Geneva, Switzerland: https://www.ramsar.org/about/wetlands-of-international-importance-ramsar-sites

[21] Birdlife International, U.K.: https://www.birdlife.org/worldwide/programme-additional-info/important-bird-and-biodiversity-areas-ibas

[22] Administered by the International Co-ordinating Council of the Man and the Biosphere (MAB) Programme, UNESCO

Figure 8: Sensitive Areas in the Area of Management



4. OVERVIEW OF SOCIO-ECONOMIC CONDITIONS

This section describes the sensitivity of socio-economic zones in the area of management to hydropower development. A description of the socio-economic condition of each zone is described in detail in **Annex E**. Background information on the overall socio-economic setting at the state and district levels is included in Annex E.A of **Annex E**.

4.1 Socio-economic Indicators

The socio-economic indicators assess the nature and extent of impacts from hydropower development in the area of management. These indicators are identified with an understanding of the communities' dependence on river resources for their social and economic wellbeing. The general impacts of HPP development unrelated to their impact on rivers, such as job creation, were excluded; such impacts were considered transient, as only a few skilled personnel will be retained for a HPP once the construction phase ends.

River-related dependence indicators key to assessing the socio-economic importance and sensitivity of segments are described below:

- *Fishing*. Fish provide food for local consumption and a source of livelihood for commercial fishers. Fishing is also important for recreational purposes and tourism. It is mainly undertaken in summers, when the fish gather at the shallow banks of the river for feeding. Commercial fish are sold in local markets and hotels. It does not form the main source of income, even for households engaged in commercial fishing. Fish are usually caught using nets, although explosives are used in some places.
- *Sand and gravel mining*. This is usually undertaken in winter (October to March) since it is easier to mine sand along the exposed beds during low flows. The mining techniques, mainly sand dredging, are crude: The sand is mined using shovels and spades before being loaded onto a trolley cart and transported to the roadside. It is then piled up along the road and sold to truck drivers passing by to collect sand for larger supply orders; in some cases, the sand is loaded onto a jeep and sold in nearby villages. In cases where sand is mined on the opposite side of the riverbank, it is transported to the road through a pulley operated by a small diesel generator. In most cases, people undertake sand mining on their own lands. Development of HPPs will alter the availability of sand and gravel in the area of management, with consequent impacts for individuals dependent on sand mining for their livelihood.
- *Tourism potential*. In the area of management, tourism potential remains largely untapped. Development of infrastructure associated with HPPs, such as roads, tunnels, reservoirs, and canals, may boost tourism. However, only winter tourism is considered in determining socio-economic sensitivity, assuming all HPPs will release sufficient water in summer. In winter, lack of flows will reduce the amount of game fish in the rivers, attracting fewer tourists; fishing may also be affected by lower water volume in hydropower reservoirs.

Information on fishing and sand mining was collected by reviewing the ESIAs of different HPPs conducted in the area of management (**section 1.7**). Both settlement-level and sampled surveys were reviewed to extract this information. Results were then extrapolated for the entire river section or zone (**section 4.2**). In zones where data was deficient or scarce, field surveys were performed (HBP 2017b).

River-related dependence on the following has not been considered for determining socio-economic impacts:

- *Cultural and religious importance*. The river does not have cultural or spiritual significance for local communities in the area of management. Mosques, shrines, or historical sites are mostly concentrated in urban areas and are not directly associated with the river. In cases where such sites were likely to be impacted by development of hydropower projects, the impacts have been evaluated in the ESIAs of individual projects.
- *Use of river water for drinking and domestic purposes*. People have negligible reliance on rivers for drinking and domestic uses, such as washing and cooking. Stream water is usually used for drinking and other purposes.
- *Irrigation*. People rely on the side streams for irrigating agricultural fields. It is difficult to bring water from the river up to the agricultural terraces.
- *Industrial use*. There is almost no industrial use of river water in the area of management.
- *Resettlement*. Settlements tend to be closer to the river, particularly in AJK where the valley is wide.

Since the bulk of the HPPs planned for AJK are run-of-river projects, large-scale resettlement is not expected.

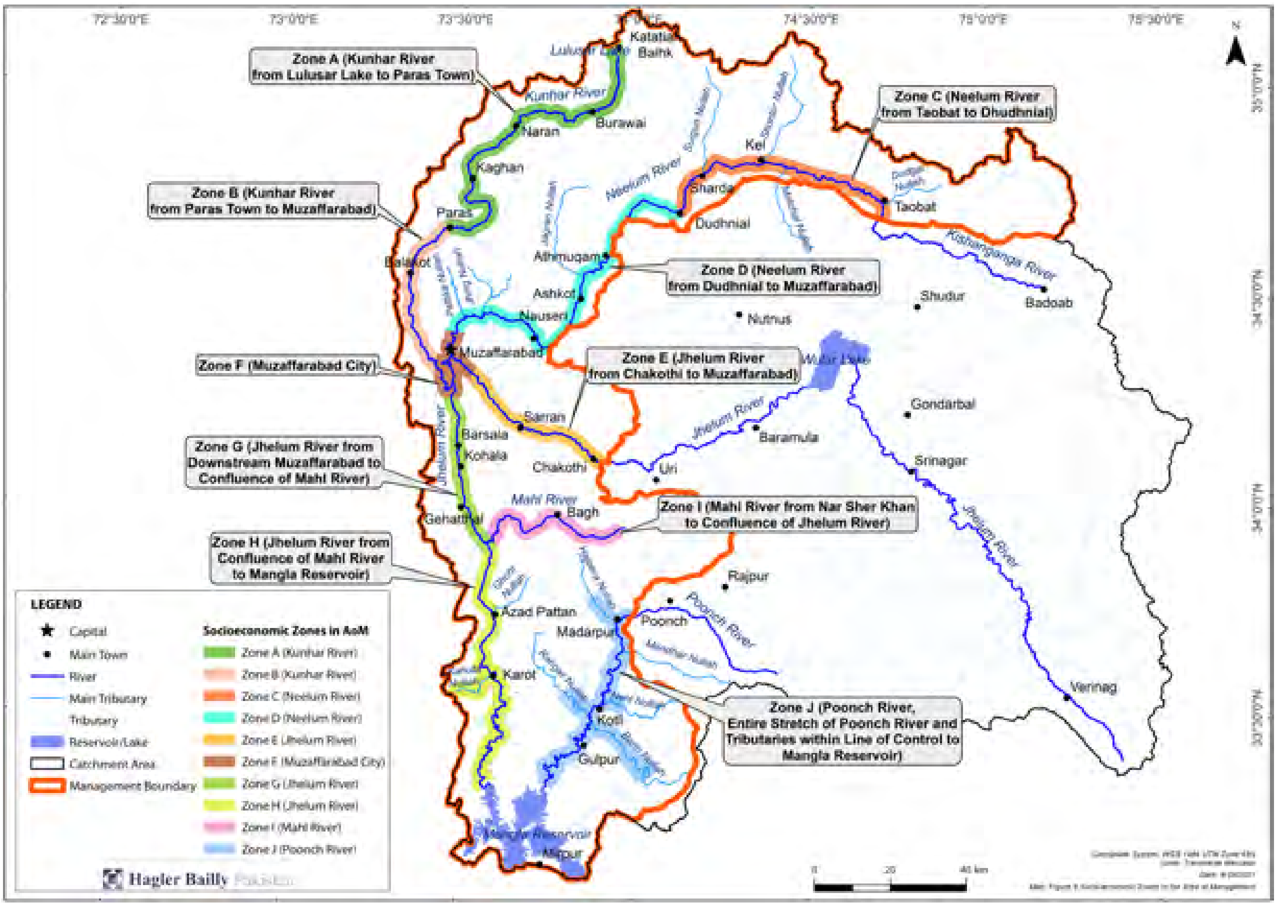
4.2 Socio-economic Zones in the Area of Management

The area of management can be delineated into the following zones, keeping in view similarities in socio-economic conditions. These zones are the same as the ecological zones defined in section 3 and are shown in **Figure 9**.

Zone A	The Kunhar River (Lulusar Lake to Paras Town)
Zone B	The Kunhar River (Paras Town to Muzaffarabad)
Zone C	The Neelum River (Taobat to Dudhnial)
Zone D	The Neelum River (Dudhnial to Muzaffarabad)
Zone E	The Jhelum River (Chakothi to Muzaffarabad)
Zone F	Muzaffarabad City
Zone G	The Jhelum River (Downstream Muzaffarabad to the confluence with the Mahl River)
Zone H	The Jhelum River (Confluence with the Mahl River to the Mangla Reservoir)
Zone I	The Mahl River (Nar Sher Khan to the confluence with the Jhelum River)
Zone J	The Poonch River (entire stretch of the Poonch River and its tributaries within the Line of Control to the Mangla Reservoir)

The Mangla Reservoir is not a natural waterbody and has been excluded from the area of management.

Figure 9: Socio-economic Zones in the Area of Management



4.3 Sensitivity Rating

This section assesses the sensitivity of each zone to hydropower development, taking into account the following indicators:

- Fishing (commercial, subsistence, and recreational)
- Sand and gravel mining
- Tourism potential

4.3.1 Methodology

Each indicator was scored for each of the 10 zones, considering the impacts of hydropower development in that zone. The outcomes are presented in **Table 7**. An indicator was given a score of "1" if impacts are likely to be very low, "2" if impacts are low, "3" if impacts are medium, "4" if impacts are high, and "5" if impacts are very high.

The Total Socio-economic Assessment Score for each zone was then calculated by adding the scores of each of the three indicators. The following system was used to make the final assessment of each zone's sensitivity to hydropower development:

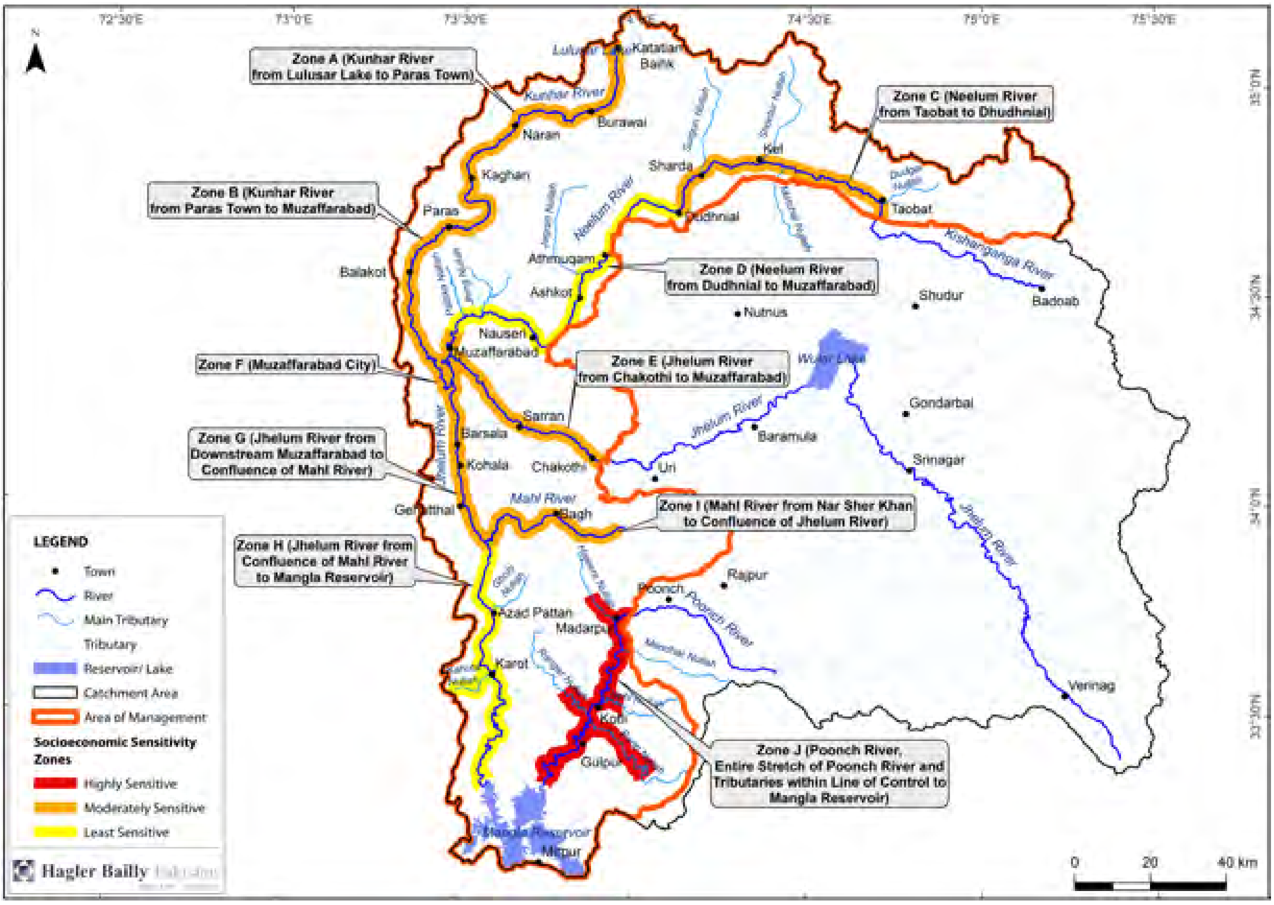
- **Least sensitivity zone**
  Total Socio-economic Assessment Score of 1–5
- **Moderate sensitivity zone**
  Total Socio-economic Assessment Score of 6–10
- **High sensitivity zone**
  Total Socio-economic Assessment Score of 11–15

The socio-economic sensitivity rating of each zone is shown in **Table 7** and the mapped sensitivity zones are shown in **Figure 10**.

Table 7: Socio-economic Sensitivity of Zones for Hydropower Development

River	Zone	Socio-economic segment	Fishing (commercial, subsistence, and recreational)	Sand and gravel mining	Tourism potential	Socio-economic assessment score	Sensitivity classification
Kunhar	Zone A	Lulusar Lake to Paras Town	Low (2)	Low (2)	Very high (5)	9	Moderately sensitive
Kunhar	Zone B	Paras Town to Muzaffarabad	Low (2)	High (4)	Medium (3)	9	Moderately sensitive
Neelum	Zone C	Taobat to Dhudnial	High (4)	Very low (1)	High (4)	9	Moderately sensitive
Neelum	Zone D	Dhudnial to Muzaffarabad	Low (2)	Very low (1)	Low (2)	5	Least sensitive
Jhelum	Zone E	Chakothi to Muzaffarabad	Medium (3)	High (4)	Low (2)	9	Moderately sensitive
Jhelum	Zone F	Muzaffarabad City	Very low (1)	High (4)	Medium (3)	8	Moderately sensitive
Jhelum	Zone G	Muzaffarabad to the confluence with the Mahl River	Low (2)	Low (2)	Low (2)	6	Moderately sensitive
Jhelum	Zone H	From the confluence of the Mahl River to the Mangla Reservoir	Very low (1)	Low (2)	Very low (1)	4	Least sensitive
Mahl	Zone I	Mahl River from Nar Sher Khan to the confluence with the Jhelum River	Low (2)	Medium (3)	Low (2)	7	Moderately sensitive
Poonch	Zone J	Entire stretch of the Poonch River and its tributaries within the Line of Control to the Mangla Reservoir	High (4)	Very high (5)	Medium (3)	12	Highly sensitive

Figure 10: Socio-economic Sensitivity Zones for Hydropower Development



4.3.2 Discussion and Conclusion

Figure 10 shows that the zones differ in their sensitivity to hydropower development as outlined below.

Highly Sensitive Zones

Zone J (Poonch River) has been categorized as highly sensitive to the construction and operation of hydropower projects. This is because: 1) fishing has high commercial, subsistence, and recreational importance in this zone, 2) sand and gravel mining is extensive and meets the requirements of a large population, and 3) potential exists for tourism in winter. People in this zone are highly dependent on the river resources compared to other zones. The following is an overview of the principle socio-economic characteristics of this zone:

- People living around the rivers catch fish for commercial and domestic use as well as for recreational purposes. Development of HPPs on rivers and streams will adversely affect fish abundance in this zone, thereby depriving locals of supplementary income. Fish species that are able to grow in run-of-river HPP reservoirs and ponds are mostly introduced and will not have the same commercial value as the endemic migratory fish.
- The construction of HPPs on rivers will change the sediment availability and alter sediment mining areas for locals. This will not only affect incomes of the locals but also lead to an increase in the costs of construction raw materials.
- Relatively warmer winters in these regions—compared to northern AJK—offers visiting opportunities to tourists from Islamabad and adjoining areas year-round. The construction and operation of several HPPs in this region is likely to bring both positive and negative impacts. Tourists looking for natural scenic surroundings will avoid these areas, but others interested in water sports may find artificial ponds and reservoirs an added attraction even during winter.
- The construction of HPPs in these zones will affect women who partly depend on these rivers for washing clothes, watering livestock, and collecting and using driftwood. They also use the riverside for recreational activities.

Moderately Sensitive Zones

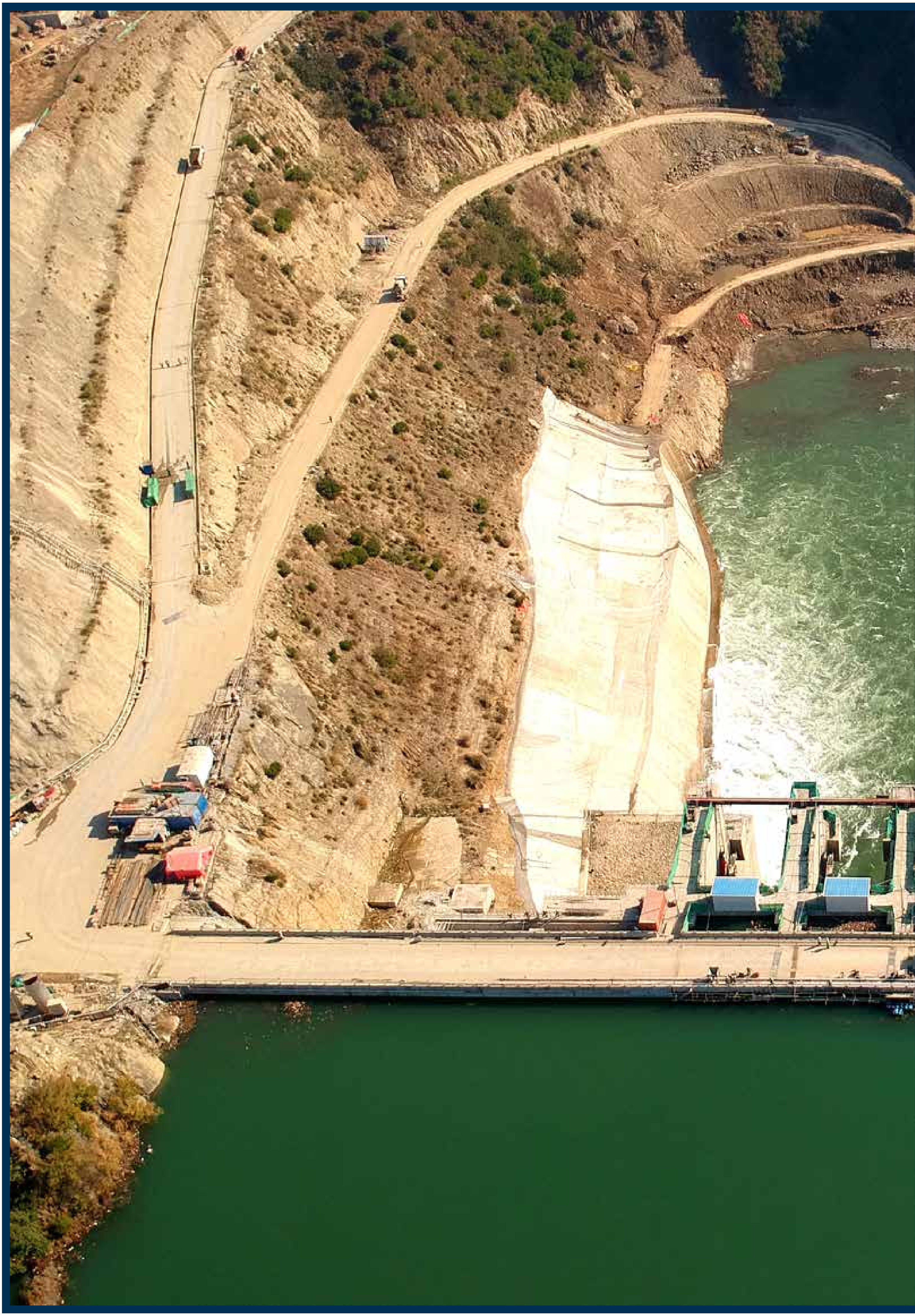
These include Zones A and B (areas around the Kunhar River from Lulusar Lake to Muzaffarabad), Zone C (areas around the Neelum River from Taobat to Dudhnial), Zones E, F, and G (areas around the Jhelum River from Chakothi to the confluence with the Mahl River), as well as Zone I (around the Mahl River). The communities in moderately sensitive zones have relatively lower dependence on commercial fishing, sand and gravel mining, and winter tourism. The following is an overview of the principle socio-economic characteristics of this zone:

- A variety of commercially valued fish species, mainly the Alwan snow trout and brown trout, provides supplementary diet and incomes to the people in these zones. The construction of HPPs will adversely affect fish diversity and abundance, thereby depriving communities of associated benefits.
- Parts of the valleys in this zone, such as the areas near Muzaffarabad, widen and provide floodplains where sand is deposited. Sand and gravel mining is prevalent in these areas and provides a source of livelihood.
- Except Zone A and Zone C, tourism in these zones is limited.

Least Sensitive Zones

Zone D and Zone H have been classified as least sensitive to hydropower development. Zone D covers the area around the Jhelum River from Dudhnial to Muzaffarabad and Zone H covers the area around the Jhelum River from the confluence with the Mahl River to the Mangla Reservoir. People living in these zones have little dependence on commercial fishing, sediment mining, and tourism. Their main occupations include government services, businesses, and daily labor.

- Although high-value commercial fish species, such as the brown trout, exist in some of these zones, the abundance of these fish is low. The construction of HPPs will have little or no impact on the livelihoods of the people living in this zone.
- There is little or no sand and gravel mining in these zones.
- There is virtually no winter tourism.



5. IMPACT ON SEDIMENTS

This section summarizes the impacts from developing multiple hydropower projects on sediment transport in the area of management. Details are provided in **Annex F**.

5.1 Overview

Dams form barriers to the transportation of much of this raw material, with sediments dropping from suspension as the river slows upon entering the reservoir. The finer sediments may stay in suspension and pass through the dam outlets during floods and, sometimes, coarser material is scoured out through bottom gates to increase storage in a sediment-choked reservoir. Thus, dams can change the total amount of sediments available to the river downstream, with a proportion of a river's sediment load possibly permanently trapped by the reservoir.

As the flow and sediment regimes of the river are altered by dams, the downstream physical environment will change in a way that reflects the interplay of these two forces. Sediments may decrease in the downstream river as they are trapped in the reservoir, causing downstream erosion, or they may increase because the remaining flow in the river is insufficient to transport the sediments still draining in from the downstream catchment. If sediments are flushed from the reservoir periodically, then periods of low sediment loads could be interspersed with intermittent periods of heavy, possibly anoxic sediments moving downstream; together, the two conditions cause extreme conditions, neither of which is natural.

In whatever way the channel adjustments play out, there will be impacts on the downstream riverine habitats, perhaps through sediments clogging important spawning grounds, habitats degrading through erosion, floodplains declining in extent and fertility, pools filling with sediments, or banks collapsing. All these changes have implications for the riverine plants and animals, as well as for cultivated land adjacent to the channel.

5.2 Impact on Sediment in the Area of Management

Introducing hydropower weirs and impoundments into the main rivers in the area of management will:

- Trap all gravels and most sand-sized material, with knock-on effects on aquatic habitats in the downstream river.
- Increase erosion in the downstream river partly as a result of sediment trapping but also through more constant discharge in narrow flow bands, which removes riparian vegetation through inundation and water logging or hydropeaking.
- Significantly alter the pattern of sand transport in the river, with sand discharge limited to periods of sediment flushing when sand will be released in high concentrations over short periods of time.

The impact of hydropower projects on sediments are outlined below:

5.2.1 Impacts on Sediment Transport

Each HPP in the Jhelum and Poonch catchments will affect the movement of sediment locally and further downstream. In the Jhelum, where there are numerous intrabasin transfers, changes in sediment loads will affect both the donor and recipient catchment. Collectively, these projects will induce major large-scale changes to the Jhelum catchment. Significant quantities of sand and gravel will be removed from the river system. The trap efficiency of each impoundment will vary and is related to the water velocity and sediment characteristics of the river. In summary:

- Smaller pulses of sand and silt captured in sediment traps upstream of powerhouses will be episodically flushed to the downstream river.
- The diversions will direct equivalent proportions of silt and clay, and lesser portions of sand, as water from one river to another. These changes will alter the dispersal patterns of sediment and affect water quality in both the contributing and receiving basin.
- The hydraulics of river channels will change: rivers from which water was diverted will experience a reduction in river energy, while rivers receiving the water will experience an increase in river flow and energy. Of particular note is the confluence of the Neelum and Jhelum rivers. Their flow and gravel delivery will decrease significantly, and the patterns of their sand delivery will be altered. Downstream, additional changes will occur because of the flow diversion from the Kunhar River into the Jhelum as well as the rapid increases in flow and river energy associated with the inflow from the Neelum-Jhelum and Kohala diversion projects.

Most of the projects plan to produce power continuously in the wet season but focus hydropower operations during peak periods. If each HPP adopts this pattern, the entire river will experience large water-level variations daily (or sub-daily). This may exacerbate erosion on the catchment as water-level fluctuations create high-river-energy conditions.

Most projects adopt a sediment-management regime based on promoting sand deposition within impoundments to minimize ingress to the turbines, thus limiting wear and tear on the infrastructure; this is combined with annual sediment flushing to maintain sufficient capacity within the impoundment and provide operational flexibility. Although some sand may be flushed annually, gravel and coarser sand will not be transported downstream until an equilibrium is reached in the impoundment, whereby the deposits reach the toe of the dam and the surface of the deposits reach the lowest outlet level. This approach will result in the deposition of deltas at the headwaters of the impoundment and may increase upstream flooding during high-flow events because of reduced channel capacity. As described in the ESIA documents, all projects will trap virtually all gravel entering the impoundment. Some projects have very low-level outlets to reduce the time needed until coarse material can be flushed downstream, but other projects will promote deposition until the sediment deposits reach the level of the sluice gates. Time frames required to achieve equilibrium vary, depending on the morphology of impoundments, rate of sediment input, and upstream activities. The loss of gravel to trapping in upstream hydropower projects or aggregate mining will reduce its availability for downstream projects, and more time will be required to achieve equilibrium.

Annual sediment flushing may have negative impacts on the downstream river system and HPPs, especially in the Lower Jhelum cascade where sediment flushed from one impoundment will directly enter the next impoundment downstream. Sediment concentrations during flushing will be very high (for example, Kohala calculated the figure at 44 kilogram per cubic meter = 44 gram per liter) and well above the natural level. These flushes can generate large turbidity plumes that propagate downstream, coating downstream riverbed and banks as well as creating "hardpan"—a distinct soil layer largely impervious to water—on exposed riverbanks once flows recede. The nature and extent of impacts will vary with distance from the dam, the flow pattern during flushing, and the flow volume and duration following the release of the large sediment load. Impacts may be mitigated if flushing coincides with high-flow events, but the risk of downstream flooding could increase during these periods.

The HPP descriptions and sediment-management approaches are based on average conditions, which rarely occur. Developers need to consider how an impoundment will be managed when an exceedingly large sediment-inflow event occurs, such as a major landslip or avalanche. In the Jhelum, the reservoirs are small compared to the "average" annual inflow-sediment volume and do not have sufficient capacity to store several years of "average" sediment loads. The amount of sediment load is highly variable and episodic events could deliver multiple times the average load within a short period. These situations would require more frequent flushing.

5.2.2 Geomorphic Impacts

The river channel immediately downstream of a dam is at high risk of scour because water discharged from the dam erodes the river, with no subsequent sediment deposition occurring.

Water diversions will reduce the rivers' sediment-transport capacity for a long distance downstream of the diversion site for most of the year. The diversions will decrease the grain size that can be transported by the river and increase sedimentation. A reduction in river levels can also promote vegetation encroachment. These processes may reduce river-channel capacity so that when a major flow event occurs, overbank flooding will be initiated at lower discharge rates than pre-dam conditions. The risk of this happening is linked to the frequency of large flood events to maintain channel capacity; the risk is lower if large flows are retained in the donor river during each monsoon season.

Channel capacity downstream of diversion projects could also decrease if sand accumulated in the impoundments is flushed down the original river channel with insufficient river energy to transport the material downstream. Flushed material deposited on riverbanks might also become cemented and poses negative impacts on riparian habitats. The steep nature of the river channels, high river energy, and inflow of additional tributaries can mitigate these risks if flushing coincides with high-flow periods.

Tributaries downstream of HPPs that divert water out of the catchment will discharge into lower base levels. This increases the tributary's water surface slope and river energy as well as erosion in its lower channel. In the river from which water is diverted, its ability to transport sediments will decrease; sediment inflows from tributaries may deposit and build "tributary bars" or infill the channel. The opposite may arise in rivers receiving additional flow, as base levels rise and tributaries adjust to a higher flow. The risk of impacts is related to the degree of flow change and relative inflow patterns of the tributaries and mainstem. If hydropower projects are truly run-of-river, then the relative timing and magnitude of flows in tributaries and the mainstem will remain unchanged and the risk is reduced.

Most impoundments are relatively small but still extend more than a kilometer upstream. Peaking operations can create fluctuating impoundment levels (for several meters a day) that may destabilize hillslopes and prevent the forming of riparian vegetation. The lack of such vegetation will lead to further bank erosion.

The grain sizes of bed material in river channels downstream of HPPs will increase as sand and gravel is transported from the channel but is not replaced.

5.2.3
Impacts on Aquatic Ecosystems

Significant changes to the flow and sediment regime of the rivers will alter the distribution and quality of aquatic ecosystems as follows:

- Gravels are a key aquatic habitat for fish. A reduction in gravel (and larger) transport through the river systems will lead to a decline in the availability of such habitats. The bedload grain-size distribution results suggest that gravel is highly transient in the rivers, with high flows rapidly transporting this material downstream. This means any gravel habitat available during the dry season would have been deposited at the end of the previous wet season and will be removed by the next high flows. Due to gravel trapping in HPPs, only gravel derived from the catchment downstream of HPP sites will be available for replenishment. The loss of gravel as a key habitat may lead to an overall decline in the fish population.
- The specific impact to an area will depend on its location in regard to the HPPs, and the area and sediment input from the unregulated catchment between the upstream HPP and the site. Impacts on specific areas may vary over time. For example, erosion and loss of gravels and sands may occur for months or even years during normal HPP operations. However, sediment flushing may bring high levels of sand and silt-sized material to the area. These factors should be considered when developing a sediment management plan.
- The conversion of rivers to impoundments will change the habitat's characteristics with respect to water depth, flow velocity, and sediment transport. Some impoundments in the Jhelum catchments are relatively small, but the establishment of a cascade will convert 145 km of free-flowing river to four ponded storages in the lower Jhelum River. The river, upstream of the Kohala discharge point, will have highly reduced flow and sediment transport as a result of the diversion of upstream projects. These two impacts will fundamentally alter the habitat characteristics of the lower Jhelum River.
- The transport of nutrient transport is linked to that of fine silts and clays. It will be similarly affected as these sediment size-fractions. Large quantities of nutrients will be diverted from river catchments and some will be trapped within impoundments. These changes will alter the availability of nutrients to the aquatic ecosystems and riparian vegetation.
- The flushing of sediments will create sizable sediment plumes that may coat and infill riverine habitats as well as blanket riparian zones with fine sediment leading to the formation of hardpans. Sediment flushing can also release high volumes of low oxygen or contaminated water from the depth of the impoundments.
- The ESIAs did not provide information on sediment quality, so it is not possible to predict whether the capture or dispersal of contaminated sediments will be an issue in the HPPs.
- Water quality in rivers may be affected by impoundment and intra-catchment diversions. Most of the proposed impoundments are relatively small, with only a few days' retention time. The risk of water-column stratification in these waterbodies is low. However, in the lower Jhelum cascade, the extended storage of water in successive impoundments poses higher risks on water quality. Light clarity is likely high in these waterbodies because of sediment settling, with increased risks of harmful algal blooms. Other water-quality risks are likely in rivers downstream of diversion projects, where the available dilution provided by river flow is substantially decreased. A potential high-risk area is Muzaffarabad, where flow rates in the combined Neelum and Jhelum rivers are predicted to drop from around 650 cubic meters per second (m^3/s) to less than 100 cubic meters per second (m^3/s) due to upstream water diversions associated with hydropower, reducing the available dilution for industrial, municipal, or domestic wastewater discharges by over sixfold (HBP 2015b). The risk is relatively low now but will increase if populations grow and industrialization intensifies.

5.2.4
Impacts on Areas of High Ecological Sensitivity

Section 3 of this report identified two areas of high ecological sensitivity within the basin: the Mahl River, a tributary of the lower Jhelum, and the Poonch River, from the Line of Control to the Mangla Reservoir.

No HPPs are planned for the Mahl River, so geomorphic changes will be limited to the confluence of the Mahl and Jhelum rivers. Due to the high degree of sediment trapping upstream of the confluence of the Jhelum and Mahl rivers, the Jhelum River channel will be at high risk of undergoing incision because of a lack of sediment deposition. This may alter the hydraulics of the confluence and increase the slope of the lower Mahl River because of a base-level reduction in the Jhelum River. Although the Jhelum River is likely to deepen, transient cobble bars may be created at the confluence because sediment deposition entering from the Mahl during high flows is not being transported by the highly regulated Jhelum River (flood flows are reduced in the Jhelum relative to the Mahl).

In the Poonch River, the timing and magnitude of sediment transport will be affected by sediment trapping upstream of the weir and the localized diversion of flow. Specific impacts are likely to include erosion downstream of the HPP. However, because there is only one HPP and accumulated sediment can be periodically flushed down the natural river channel, a sediment management plan can be developed to promote sediment movement through the impoundment to minimize downstream impacts.

5.2.5 Socio-economic Impacts

This section presents an overview of socio-economic impacts from sediment load changes and availability in the area of management. The socio-economic dependence of the local communities is described in **Annex E**.

As discussed in **section 5.2.1**, bedload will be trapped while suspended sediment and sand fractions will be released when the reservoirs are flushed. Sediments are expected to accumulate in the reservoirs for between five and 15 years, although the actual length will vary depending on the reservoir size, sediment inflow, and flushing design. As the cascade of hydropower projects comes into place, the following outcomes are expected:

Boulders, Cobbles, and Gravels

Boulders, cobbles, and gravels (bedload) for mining will be available only in the river segments upstream of the dams that are first in the catchments. This means the Suki Kinari HPP in the Kunhar River, the Athmuqam HPP or Dudhnial HPP in the Neelum River, the Kohala HPP in the Jhelum River, and the Gulpur HPP in the Poonch River. Floods will deposit the bedload in the reservoirs where heavier fractions will settle at the upstream end of reservoirs. Downstream of dams of these projects, sediment will flow in from the tributaries into the reservoirs or be deposited in the main stem from where it could be mined.

Following the dam's construction, the mining of boulders, cobbles, and gravel could be directed to the upstream end of reservoirs where these fractions will settle. Larger boulder fractions will settle first and likely remain in place as the water velocity will not be high enough to move them even during high floods. Miners also cannot remove the larger boulders given their weight. Cobble and boulder deposits will gradually move toward the dam but could still be mined once deposited. Initially, dam operators may want to see a build-up of deposits to restrict the movement of cobbles and gravel toward the dam. Later on, however, they would likely prefer removing cobbles and gravels at the upstream end of reservoirs to maintain storage levels and extend reservoir life. Access, if not already available, may need to be provided to the community to reach the deposited sediments at the upstream end of the reservoirs.

Suitability of cobbles collected from riverbeds for aggregate production should also be investigated. The hydropower industry does not use aggregate produced from sediment mined from riverbeds, as the strength achieved in concrete does not meet the specifications. It is likely that the aggregate produced from cobbles collected from riverbeds is not suitable for the construction of residential and commercial buildings, particularly for reinforced-cement-concrete structures. Further studies are needed to determine the risks involved.

Sand

Availability of sand will be initially restricted when reservoirs reach an equilibrium. Some sand will be released from the sand traps installed at the dams to reduce the flow of sediments into the powerhouse turbines. After the reservoirs have reached an equilibrium, coarser sand fractions will be flushed typically once a year, but sand will not be available downstream for the rest of the year. Communities can mine sand, but the location of sand deposits will shift as the dams are constructed and operated. The socio-economic impacts related to the availability of sand after reaching equilibrium will therefore be limited and manageable. As in the case of cobbles and gravels, access may have to be provided to the community to reach the deposited sediments.

5.2.6 Impacts on Other HPPs

Sediment flushing will affect downstream rivers and HPPs. For example, the lower Jhelum River will experience large inflows of water and sediment whenever the Neelum-Jhelum, Kohala, or Patrind projects implement flushing. Simultaneous flushing by the projects may create huge sediment loads and floods in the lower river. Managing these flushes will require coordination to maintain water levels within safe limits and prevent the deposition of large sediment volumes within the lower impoundments.

Flushing within the cascade (for example, from Mahl to Azad Pattan) will require similar coordination.

If flushing coincides with high-flow events, sediment and water pulses, combined with natural inflows, may increase flooding, especially if the channel has been infilled by sediment from tributaries.

Once the impoundments reach equilibrium with incoming bed material, flushing may become viable. In the lower cascade, the movement of large material from one project into the headwaters of the next downstream can increase bed levels and affect storage capacity.

Flushing at the end of the wet season has been proposed to increase water-storage capacity for peaking during the dry season. This could increase sedimentation in the downstream river channel, reducing its capacity for the first high-flow events of the following monsoon season.

5.3 Summary of Findings

To develop a sustainable hydropower development strategy, it is important to answer the following questions on changes in sediment transport in the catchments:

- *Which reservoirs will trap bedload sediment?* All reservoirs are predicted to trap nearly all bedload sediment. Sediment flushing is expected to mobilize sand, but bedload comprising gravel and coarser material will remain trapped until equilibrium is achieved and the material can move downstream through a gate. Bedload transport will continue and increase in unregulated reaches of the lower rivers and abruptly end at each impoundment before recommencing downstream of the dam. However, the riverbeds downstream of impoundments will be armored as material is transported but lesser of it becomes available as bedload. This punctuated capture of material, combined with armoring of the riverbeds, will disrupt the connectivity of the river system and promote major geomorphic changes. New HPPs constructed upstream of existing projects will capture the bedload, meaning there will be less input for the downstream projects in operation. Because of this, it is difficult to determine when impoundments will achieve equilibrium with bedload transport.
- *When will hydropower projects attain equilibrium with the sediment load?* HPPs are unlikely to ever achieve a true equilibrium because of numerous factors controlling sediment transport and HPP operations. Over years to decades, a dynamic equilibrium will be reached reflecting the variability of the system, including:
    - o Variable sediment loads and delivery patterns
    - o Episodic extreme events resulting in the delivery of large instantaneous loads
    - o The flushing regime implemented at a HPP
    - o The operating regime of a HPP, which can result in the movement of material into different parts of the impoundment
    - o The operations of upstream HPPs affecting bedload and sand inputs

  According to the ESIAs of hydropower projects, it usually took several decades before the active storage capacity of the impoundments reached an equilibrium with the incoming sediment load. However, these predictions were based on annual sediment loads, annual flushing, assumptions about the efficacy of flushing regimes, and catchment conditions; they did not incorporate the impacts of upstream HPPs on sediment transport. For example, the Mahl HPP is unlikely to receive its estimated sediment load of 30 metric tons per year for decades into the future owing to the capture of material in upstream impoundments (SIDRI 2017). Therefore, time frames for achieving a sediment equilibrium within impoundments is contingent on each impoundment upstream achieving a balance.
- *How will sediment patterns change above and below each HPP?* Sediment trapping will reduce the daily transport of sand and coarser material downstream of HPPs, with episodic pulses of sand released from impoundments. Diversion projects will reduce the transport of silt and clay downstream in the donor basin and increase transport in the receiving basin. The diversion of water will also affect the transport capacity of rivers downstream of diversions, promoting large-scale geomorphic response of the river channel, such as narrowing and infilling. Sediment transport upstream of HPPs will be affected by sediment trapping and operations of existing upstream HPPs.

5.4 Information Gaps

The available sediment information provides an internally consistent, large-scale picture of sediment transport in the catchments. The most recent results were already 10 to 20 years old, so sediment- regime changes associated with catchment development or climate change over the past two decades have not been reflected in the data sets and are beyond the scope of this project. Before a robust understanding of climate-related changes could be gained, it is necessary to find out how existing hydropower stations and catchment activities have been affecting sediment transport.

While the existing information provides a catchment overview, information about local geomorphic processes is missing. These localized, reach-based relationships have a controlling influence over the biodiversity and ecosystem conditions of in-channel and riparian habitats.

A key question about sediment transport in the future is the uncertainty associated with how HPPs will operate versus how they are proposed to operate. Of particular concern is the lack of established systems to coordinate sediment flushing among different projects.

These information gaps could be addressed, at least partially, by implementing the following:

- Measure bedload movement using the Acoustic Doppler Current Profiler technology. This instrument normally measures discharge but can be adapted to calculate the average rate of bedload movement across a river profile. Other remote-sensing techniques could also be used to obtain in situ grain-size. These types of measurements would provide a quantitative understanding of bedload movement and sediment size that are critical for understanding sediment transport in river systems.
- Map the sediments forming in-channel habitats, such as gravel beds or sand bars, at a reach scale. This information would allow a better understanding of how these critical habitats will likely change under altered sediment-transport and flow regimes. Photo-monitoring points could be set up to take repeat photos from the same vantage point to capture changes to sediment and channel characteristics.
- Based on the river-reach maps, quantify the relationship between discharge and sediment movement, particularly reach-specific information on the sorting of sediment size-fractions to form habitats. This information is necessary to devise proper environmental-flow (EFlow) regimes.
- Gather more information about how HPPs will operate and be coordinated. The operations of HPPs will combine to produce an entirely new flow and sediment regime in the river. An understanding of the interaction of individual regimes, such as in terms of sediment flushing, is needed to identify the right management strategies. This can be done through a catchment hydropower user group or equivalent.

6. IMPACT ON ECOLOGY

This section summarizes the development impacts from multiple hydropower projects on the basin's aquatic and terrestrial ecology. Details are provided in **Annex G.**

6.1 Impacts on Aquatic Ecology using DRIFT Modelling

Impacts on the aquatic ecological resources were assessed using the DRIFT Decision Support System (DSS), an internationally recognized software model that employs a multidisciplinary team to analyze the likely effects of a range of environmental-flow (EFlow) scenarios. DRIFT aims to produce predictions of change in three streams of information—ecological, economic, and social—representing the three pillars of sustainable development. It incorporates a custom-built DSS that holds all the relevant data, understanding, and local knowledge about the river provided by river and social specialists.

The DRIFT model for the Jhelum-Poonch River Basin (Jhelum DSS) was configured by Southern Waters and HBP with support from IFC (HBP 2018c). A conservative assessment was conducted for a base case assuming flow alterations and barriers to migration created by dams. Impacts on ecosystem integrity (**Table 8**) were assessed assuming no management. This model has been updated for this study by combining and extending the DRIFT DSSs used to assess the EFlows of individual HPPs in the Jhelum-Poonch Basin since 2010, namely the Gulpur HPP, the Karot HPP, the Kishanganga HPP, the Kohala HPP, and the Neelum-Jhelum HPP.

The consolidated DRIFT DSS comprises 25 EFlow sites: 20 on the mainstem rivers (the Neelum, the Jhelum, and the Poonch) and five representing key groups of nullahs (**Figure 11**).[23] The scenarios analyzed, including the management or protection levels in the rivers and changes in the ecological and fish integrity, are summarized in **Annex G**, while the complete DRIFT report is provided in Annex G.A of **Annex G.**

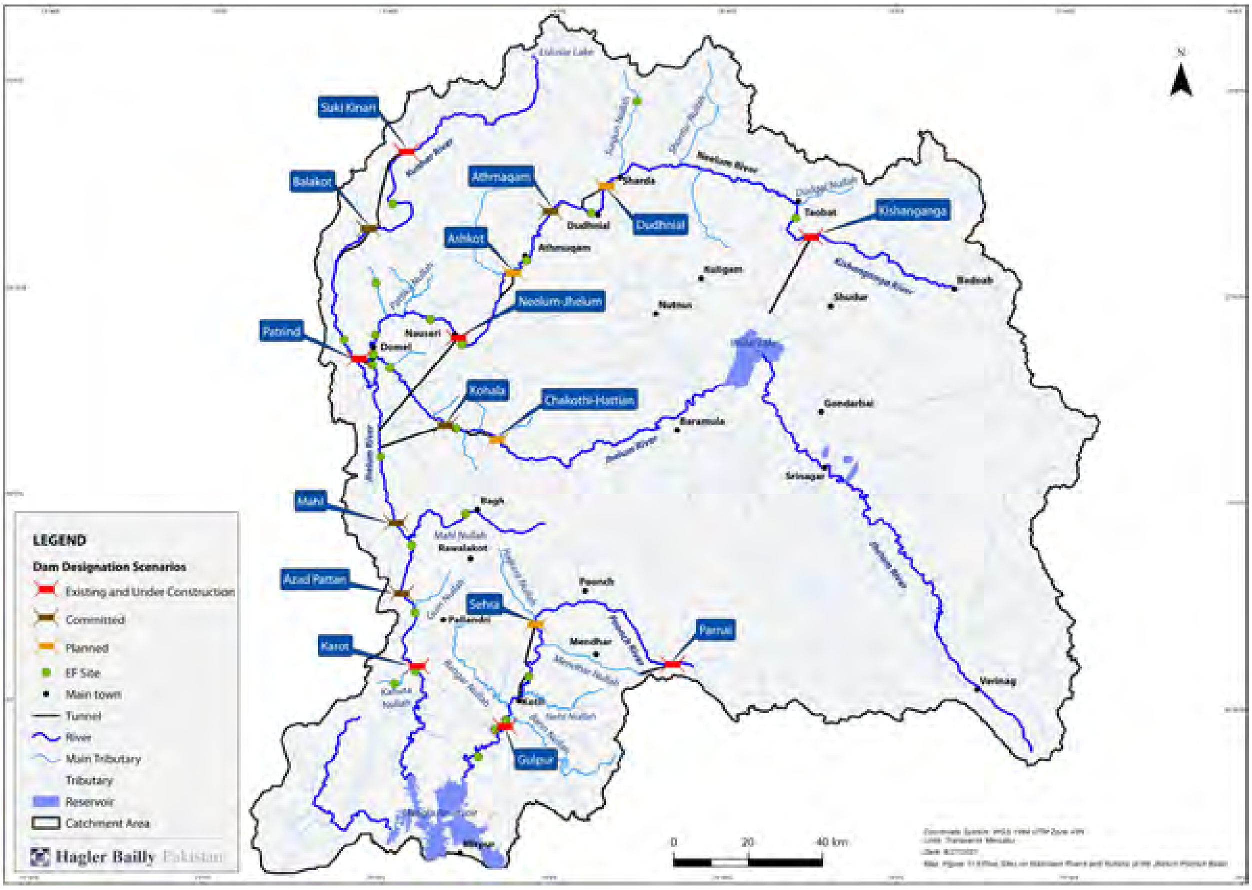
Table 8: Ecosystem Integrity

Ecosystem integrity is an indication of the ecological condition of a part of the ecosystem (such as habitats or fish communities) or of the whole ecosystem relative to its natural condition. Integrity is expressed as an ecological category from A to F as defined below.

Ecological category	Description of the habitat
A	Unmodified: the habitat is still in a natural condition.
B	Slightly modified: a small change in natural habitats and biota has taken place, but the ecosystem functions have essentially remained the same.
C	Moderately modified: loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified: a large loss of natural habitat, biota, and basic ecosystem functions has occurred.
E	Seriously modified: the loss of natural habitat, biota, and basic ecosystem functions is extensive.
F	Critically/extremely modified: the system has been critically modified with an almost complete loss of natural habitat and biota; in the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

23 EFlow sites are river reaches representative of considerably longer sections of a river. They are the focus sites whose hydrology and hydraulic relationships are computed for use in a EFlow assessment.

Figure 11: EFlow Sites on Mainstem Rivers and Nullahs of the Jhelum-Poonch Basin



Note: Map shows the hydropower projects modelled in the Basin-Wide DRIFT DSS.

6.1.1 Results of Scenario Analysis

Scenarios Assessed

Impacts on the aquatic ecological resources were tested using the DRIFT DSS, which evaluated scenarios comprising three levels of HPP development (excluding developments on the nullahs), two levels of management of the downstream river reaches and key tributaries, and variations on HPP operations, including sediment flushing and peaking versus baseload power generation. For each scenario, the DSS predicted overall river condition based on an assessment of changes in key indicators for the next 30 years starting from 2012, with the intervening period defined by the provisions of the scenario.

The three levels of HPP development were defined as: 1) existing or under-construction HPPs; 2) committed HPPs, meaning detailed engineering is at an advanced stage, tariff application at the engineering, procurement, and construction stage has been submitted or approved by the electricity regulator, or a letter of support has been issued by the government; and 3) planned HPPs, meaning a feasibility study has been prepared and a letter of intent has been issued by the government, but detailed engineering has not started (or is at an early stage) and investors other than the initial developer have not been secured.

The two management levels were based on peak power or baseload power generation and the EFlow releases outlined in **Table 9** and the various management levels agreed with HPP companies outlined in **Table 10**.

The two management levels were defined as:

- "Agreed," incorporating various management provisions between the government and individual HPP companies
- "High," which has more stringent protection levels for the environment than the "agreed" scenario; examples include higher EFlow releases from the Neelum-Jhelum HPP (22.5 m^3/s instead of 9 m^3/s) and baseload instead of peaking operations at the Neelum-Jhelum and the Kishanganga HPPs.

A stakeholder workshop was held in Islamabad in January 2018 to review and test the scenarios encompassing individual changes in flow regime, sediments, management, and fish migration. Participants included hydropower developers and representatives from the environmental protection agencies as well as fisheries and wildlife departments of AJK, KP, and Punjab provinces.

For each scenario, predicted changes in the river ecosystem are presented as a change in overall ecosystem integrity relative to baseline (BASE 2012 Pro 1) for the river reach represented by each EFlow site. Ecosystem integrity is classified using categories A to F (**Figure 12**) (Kleynhans 1996).

Table 9: Scenarios Assessed in This Report

Subbasin	HPP	Existing and under-construction		Committed		Planned	
		Agreed management	High management	Agreed management	High management	Agreed management	High management
Neelum	Kishanganga	9 m³/s	9 m³/s	9 m³/s	9 m³/s	9 m³/s	9 m³/s
	Dudhnial					Baseload	Baseload
	Ashkot					Baseload	Baseload
	Athmuqam			Baseload	Baseload	Baseload	Baseload
	Neelum-Jhelum	Peaking EFlow release (9 m³/s)	Baseload/ higher EFlow release (22.5 m³/s)	Peaking EFlow release (9 m³/s)	Baseload/ higher EFlow release (22.5 m³/s)	Peaking EFlow release (9 m³/s)	Baseload/ higher EFlow release (22.5 m³/s)
Kunhar	Suki Kinari	Peaking	Peaking	Peaking	Peaking	Peaking	Peaking
	Balakot			Baseload	Baseload	Baseload	Baseload
	Patrind	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
Upper Jhelum	Wular					Baseload	Baseload
	Lower Jhelum	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Uri I	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Uri II	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Chakothi-Hattian					Baseload	Baseload
	Kohala	Peaking EFlow release (30 m³/s)	Baseload EFlow release (30 m³/s)	Peaking EFlow release (30 m³/s)	Baseload EFlow release (30 m³/s)	Peaking EFlow release (30 m³/s)	Baseload EFlow release (30 m³/s)
Lower Jhelum	Mahl			Peaking	Baseload	Peaking	Baseload
	Azad-Pattan			Baseload	Baseload	Baseload	Baseload
	Karot	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
Poonch	Parnai			Baseload	Baseload	Baseload	Baseload
	Sehra			Baseload	Baseload	Baseload	Baseload
	Gulpur	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload

Table 10: Protection Levels for River Reach Represented by Each EFlow Site

River reach represented by			Agreed management	High management
Neelum	1	Line of Control	Pro 1	Pro 1
	2	Surgun Nullah	Pro 1	Pro 1
	3	Dudhnial	Pro 1	Pro 1
	4	Athmuqam	Pro 1	Pro 1
	5	Jagran Nullah	Pro 1	Pro 1
	6	Nauseri (0)	Business as usual	Pro 2
	7	Panjgiran	Business as usual	Pro 2
	8	Patikka Nullah	Business as usual	Pro 2
	9	Dhanni	Business as usual	Pro 2
	10	Muzaffarabad	Business as usual	Pro 2
Upper Jhelum	11	Upstream Kishanganga	Pro 3	Pro 3
	12	Subrey	Pro 3	Pro 3
Kunhar	13	Khanian	Business as usual	Pro 2
	14	Paksair	Business as usual	Pro 2
Lower Jhelum	15	Ambor-5	Pro 3	Pro 3
	16	Kohala-6	Business as usual	Pro 2
	17	Mahl Nullah	Business as usual	Pro 3
	18	Mahl DS	Business as usual	Pro 2
	19	Azad Pattan	Business as usual	Pro 2
	20	Kahuta Nullah	Pro 2	Pro 2
	21	Hollar-7	Pro 2	Pro 2
Poonch	22	Kallar Bridge	Pro 2	Pro 3
	23	Borali Bridge	Pro 2	Pro 3
	24	Gulpur Bridge	Pro 2	Pro 3
	25	Billiporian Bridge	Pro 2	Pro 3

Note: Pro 1 = 2013 pressures fixed for the next 30 years; Pro 2 = 2013 pressures halved over the next five years and then stable at that level for the next 25 years; Pro 3 = reduce 2015 levels of non-flow-related pressures by 90 percent, that is, decline in pressures (relative to 2015) over time (only applied for Kohala HPP).

Figure 12: Ecological Integrity Ratings

Ecological category	Corresponding DRIFT integrity	Description of the habitat
A	>−0.25	Unmodified: the habitat is still in a natural condition.
B	>−0.75	Slightly modified: a small change in natural habitats and biota has taken place, but the ecosystem functions have essentially remained the same.
C	>−1.5	Moderately modified: loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	>−2.5	Largely modified: a large loss of natural habitat, biota, and basic ecosystem functions has occurred.
E	>−3.5	Seriously modified: the loss of natural habitat, biota, and basic ecosystem functions is extensive.
F	<−3.5	Critically/extremely modified: the system has been critically modified with an almost complete loss of natural habitat and biota; in the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

The overall ecosystem integrity for each EFlow reach associated with each scenario is summarized in **Table 11** and shown in **Figure 13**.

The DSS provides estimated mean percentage change from baseline in the abundance, area, or concentration of the indicators (these are tabulated in **Annex G**).

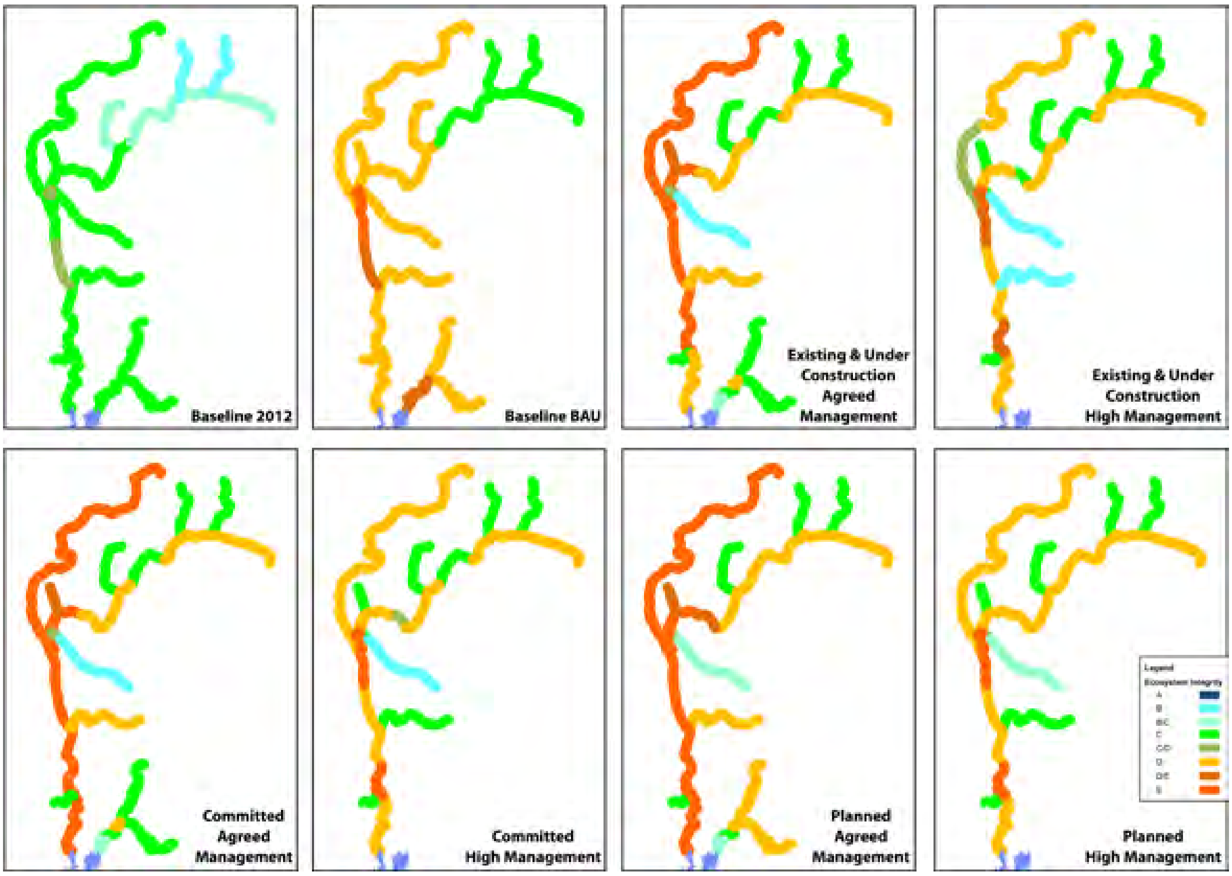
To calculate integrity, the absolute predicted score for each indicator was assigned a positive (+) or negative (–) value to show whether an increase in that indicator would represent a move toward or away from the natural condition of the river. For instance, an increase in an indigenous fish species would be positive for integrity, while an increase in an exotic fish would be negative for integrity. Discipline integrity ratings were then calculated from the abundance changes. The integrity ratings for each discipline were then combined to provide an overall ecosystem integrity (Brown et al. 2008).

Table 11: Overall Ecosystem Integrity for Each EFlow Reach of Each Scenario

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) Business As Usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Neelum	Line of Control	B/C	C	D	D	D	D	D	D	D	D
	Surgun Nullah	B	C	C	C	C	C	C	C	C	C
	Dudhnial	B/C	C	C	C	C	C/D	C	C	D	D
	Athmuqam	C	D	D	D	D	D	D	D	D	D
	Jagran Nullah	B/C	D	C	C	C	C	C	C	C	C
	Nauseri	C	D	D	C	C	C/D	D	C/D	D/E	D
	Panjgiran	C	D	E	D	D/E	D	E	D	E	D
	Pattika Nullah	C	D	D/E	C	C/D	C/D	D/E	C	D/E	C
	Dhanni	C	D	E	C	D/E	D	E	D	E	D
	Muzaffarabad	D	E	E	E	E	E	E	E	E	E
Upper Jhelum	Upstream Kohala HPP	C	D	B	B	B/C	B/C	B	B	B/C	B/C
	Subrey	C	D	C/D	C	D	C/D	C/D	C	C/D	C/D
Kunhar	Khanian	C	D	E	D	D	D	E	D	E	D
	Paksair	C	D	E	C/D	D	D	E	D	E	D
Lower Jhelum	Ambor	C/D	E	E	D/E	E	E	E	E	E	E
	Kohala	C/D	D/E	E	D	D/E	D/E	E	D	E	D
	Mahl Nullah	C	D	D	B	B/C	B/C	D	C	D	C
	Mahl DS	C	D	E	D	D	D	E	D	E	D
	Azad Pattan	C	D	E	D/E	E	E	E	E	E	E
	Kahuta Nullah	C	D	C	C	C	C	C	C	C	C
	Hollar	C	D	D	D	D	D	E	D	E	D
Poonch	Kallar Bridge	C	D	C	Not run			C	Not run	D	Not run
	Borali Bridge	C	D/E	D				D		D	
	Gulpur Bridge	C	D/E	C				C		C	
	Billiporian Bridge	C	D/E	B/C				B/C		B/C	

Note: SF-4 = April sediment flush; SF-8 = August sediment flush.

Figure 13: Predicted Overall River Condition for Scenarios Tested Using DRIFT



Note: See **Figure 1** for a detailed map showing the rivers and their names.

Results

Overall, the gradual increase in the number of hydropower projects in the Jhelum-Poonch Basin will be accompanied by:

- A decline in sand and gravel availability in the rivers. This may be partially offset by the flushing of sand-sized sediments, but gravels cannot be flushed from the reservoirs for many years. The time required for a new equilibrium to become established depends on the rate of sediment input, which is governed by the frequency, magnitude, and duration intensity of rainfall, sediment supply, and the flushing regimes at the HPPs (frequency, duration, rate, and degree of impoundment drawdown).
- An increase in the availability of cobble and boulders. This is mainly because they will become exposed as sands and gravels are eroded and not replaced because they are trapped in upstream reservoirs.
- This effect is unlikely to persist for a great distance downstream of any single HPP, particularly in the upper parts of the basin, because of the high sediment supply from the hillslopes (landslides). It may be more problematic downstream, where less sediment is supplied by the slopes and the cumulative impacts of many HPPs has a greater effect on supply.
- Reduced habitat diversity directly linked to lower sediment supply and increased erosion. This is likely to affect breeding habitats, as many spawning fish tend to favor gravel habitats.
- Changes in habitats and the knock-on effects on other aspects of the river ecosystem, such as downstream riparian vegetation and macroinvertebrates that provide much of the fish food, will reduce fish abundance.
- Sediment flushing will unlikely alleviate the negative impacts because it results in large and simultaneous supplies of sediments that are difficult to sort or move downstream. The net effect is often localized smothering of habitats rather than a reset to more natural sediment-supply levels in a whole river reach.
- The large migratory fish species, such as the brown trout and golden mahseer, will be particularly hard hit as the insurmountable HPP weirs will lead to a progressive decline in their home range.
- It is worth noting that the proposed HPPs all have extensive reservoirs, which will result in deeper, lake-like habitat unsuitable for colonization by

most river species. This will significantly transform the nature of the aquatic ecosystems in the Jhelum-Poonch Basin.

The fish-integrity results, presented separately in **Table 12**, show several interesting effects, such as the impact of upstream HPPs on rivers downstream of other HPPs. For instance, at Hollar in Lower Jhelum River, fish integrity under the agreed-management scenario is an “E” even through the agreed management is Protection Level 2 because it is expected that peaking from the Neelum-Jhelum and Kohala HPPs will not be attenuated by the Karot reservoir, leading to wide flow fluctuations in the downstream river daily. However, under high management, both HPPs will operate as baseload plants and fish integrity at Hollar is expected to improve to a “D” category (**Table 12**). Thus, the efforts of management at the Kishanganga HPP in protecting the downstream river may be contradicted by operation of upstream HPPs. Other knock-on effects are also evident; for example, sediment flushing will negatively affect fish in the mainstem and have a knock-on effect on fish integrity in Kahuta Nullah as some species will migrate from the main river to the nullah.

Table 12: Fish Integrity for Each EFlow Reach of Each Scenario

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) Business As Usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Neelum	Line of Control	B	D	D	D	E	E	D	D	D	D
	Surgun Nullah	B	C	B	B	C	B/C	B/C	B/C	B/C	B/C
	Dudhnial	B	D	C	C	E	E	C/D	C	D	D
	Athmuqam	C	D	D	D	E	E	D	D	D/E	D/E
	Jagran Nullah	B	D	C	B	C	C	C	B	C	C
	Nauseri	C	D/E	E	C	E	E	E	C	E	C
	Panjgiran	C	D/E	E	E	E	E	E	E	E	E
	Pattika Nullah	C	E	E	E	E	E	E	E	E	E
	Dhanni	C	E	E	E	E	E	E	E	E	E
	Muzaffarabad	D	E	E	E	E	E	E	E	E	E
Upper Jhelum	Upstream Kohala HPP	C	E	A	A	B	B	A	A	A	A
	Subrey	C	E	D	D	E	E	D	D	D	D
Kunhar	Khanian	C	E	E	C	E	E	E	C/D	E	C/D
	Paksair	C	E	E	C/D	E	E	E	D	E	D
Lower Jhelum	Ambor	D	E	E	E	E	E	E	E	E	E
	Kohala	D	E	E	D	E	E	E	E	E	E
	Mahl Nullah	C	E	E	A	A	A	E	A/B	E	A/B
	Mahl DS	C/D	E	E	D	E	E	E	E	E	E
	Azad Pattan	C	E	E	C/D	E	E	E	D/E	E	D/E
	Kahuta Nullah	C	E	D	B	D	C/D	D	B/C	D	B/C
	Hollar	C	E	E	D	E	E	E	D	E	D
Poonch	Kallar Bridge	D	E/F	C	Not run			C	Not run	D	Not run
	Borali Bridge	D	F	F				F		F	
	Gulpur Bridge	D	F	B				B		B	
	Billiporian Bridge	D	F	A/B				A/B		A	

Note: SF-4 = April sediment flush; SF-8 = August sediment flush.

The results are discussed in terms of the main subbasins, namely:

- The Neelum River upstream of the confluence with the Jhelum River
- The Kunhar River
- The Upper Jhelum River from the Line of Control to the confluence with the Neelum River
- The Lower Jhelum River from the confluence with the Neelum River to the Mangla Reservoir
- The Poonch River

The outcomes of the scenarios and the reasons behind are broadly consistent across the different versions of the DRIFT DSS. Nonetheless, the 2018 version (this version) does return slightly different results from those of the 2016 version. The differences are related to the updates to the DSS explained in Annex G.A of **Annex G** and changes in the response curves of the geomorphological indicator to incorporate information from the sediment audit (Annex G.A of **Annex G**). For the most part, these are also consistent with the previous version. The single exception is the direction of change predicted for cobble and boulder bars. The explanations in the 2016 DRIFT DSS mentions that sand overlies cobbles, meaning when sand is lost from the system, the result—at least in the short-term—would increase the exposure of the cobble bars. This is how the channel will armor: It will first lose sand and gravel to expose cobbles; over time, because the cobbles are trapped in the HPPs, their amount in the system will fall and the cobble bars themselves will also be washed away. However, it is assumed that this eventuality will take longer than the 30 years modelled in the DSS. The cumulative impacts on the aquatic ecological resources can be summarized as follows:

- Most of the impacts in the **Neelum River** occur under the scenario of existing and under-construction HPPs, such as the Kohala and Neelum-Jhelum HPPs. Adding the Athmuqam HPP (committed) and Dudhnial HPP (planned) will lead to incremental impacts on key indicators and a slight decrease in the overall condition of the river downstream of these HPPs than under the existing and under-construction scenario. This is partly because the Athmuqam and Dudhnial HPPs will operate as true run-of-river baseload plants—that is, hourly flow entering the impoundment equals released flow—and have little influence on downstream flows. They will act as barriers to fish migration and sediment, but their influence is expected to be offset by the large tributaries entering the Neelum River upstream and downstream of these two HPPs. The lack of change in overall integrity at Muzaffarabad under high management hides the fact that there is a noticeable reduction in nutrient concentration and better water quality, which will have a knock-on effect on macroinvertebrates and fish.
- The results for the **Kunhar River** mainly reflect the drop in condition under the business-as-usual scenario and the barrier effects on fish (mainly Alwan snow trout) from the Patrind, Balakot, and Suki Kinari HPPs. The individual indicator results show slight incremental impacts after adding the Balakot and Suki Kinari HPPs to the impacts of the Patrind HPP. As is the case for the Neelum River, the high-management scenario results in a more favorable overall integrity because of improved protection levels against non-flow-related impacts in the subbasin.
- The **Upper Jhelum River** is affected by the Kishanganga and Kohala HPPs in the existing and under-construction scenario. In this scenario, the reaches upstream of Kohala and at Subrey are modelled under Protection Level 3 under agreed management, which prohibits any use of the river resources. This, combined with the enhanced dry-season flows supplied by the Kishanganga HPP, improves the integrity of the river upstream of Kohala HPP. The River downstream of Kohala HPP, however, is affected by major changes to the minimum dry-season discharge and the onset and duration of the wet and dry seasons. With the Chakothi-Hattian HPP (modelled as a baseload plant with some sediment flushing) in place, the reaches upstream of Kohala HPP deteriorates slightly mainly because of the HPP's barrier effect on fish migration and sediment supply. The high management without sediment flushing does not yield major changes in the predicted outcomes. Flushing sediment down the Jhelum River, however, is expected to have negative consequences for the ecosystem, primarily fish. This is mainly because when sediments are periodically flushed from the reservoir, periods of low sediment loads could be interspersed with intermittent periods of heavy, possibly anoxic sediments moving downstream—neither is natural and can cause extreme conditions. In whichever way the channel adjustments play out, downstream riverine habitats and biota will be affected, perhaps through lack of oxygen to support life or sediments clogging the gills of macroinvertebrates and fish as well as important habitats including spawning grounds.
- The existing and under-construction HPPs on the **Lower Jhelum River** include Kishanganga, Neelum-Jhelum (tailrace outlet), Patrind, Karot, and Kohala (tailrace outlet). In this scenario, the condition of the reach of the Mahl's dissolved solids is slightly enhanced by its proximity to the Mahl Nullah. The Kohala, Mahl's dissolved-solids, and Azad Pattan reaches are heavily affected by the fluctuating flows

daily in the dry and transitional seasons as a result of peaking power generation at the Neelum-Jhelum and Kohala HPPs. These effects might extend to the Azad Pattan and Kohala reaches but are not currently captured by the DRIFT DSS. The benefit to all three sites will increase if the Mahl Nullah is given greater protection. The impacts for the existing and under-construction scenario can also be reduced by running the Neelum-Jhelum and Kohala HPPs as baseload plants. Although the committed Mahl and Azad-Pattan HPPs are both modelled as baseload plants, they in fact peak involuntarily as a result of the peaking effects from the Neelum-Jhelum and Kohala HPPs. Fish and sediments in these reaches are also heavily affected by the barrier effect of the weirs associated with the Mahl and Azad-Pattan HPPs.

- The first two scenarios in the **Poonch River** include only the Gulpur HPP and reflect the operating rules and protection provisions already agreed or implemented for this HPP. The planned scenario, which includes the Sehra HPP, is expected to lead to a slight decrease in the condition of the Poonch River upstream of the Gulpur HPP. This minor change in overall integrity, however, belies a reduction of 20 to 30 percent decline in species such as the Alwan snow trout and Pakistani labeo.

Summary and Conclusion

This report covers more technical DSS adjustments done to improve data handling in the Jhelum-Poonch Basin-Wide DRIFT DSS, which was created in 2016 using the individual DSSs developed in EFlow studies for the Gulpur, Karot, Kishanganga, Kohala, and Neelum-Jhelum HPPs.

The scenarios presented here illustrate the cumulative impacts associated with progressive development of HPPs on the mainstream rivers of the Jhelum-Poonch Basin and the possibilities for mitigating these impacts through management and operation (peaking versus baseload power production and sediment flushing). They excluded developments on the nullahs as it was not possible to source the hydrological data needed to model these in the time frame required. The scenarios do, however, include management options for the nullah groups.

At the current level of site-specific data and expert consideration given to the response curves in the DSS, it would be unwise to extend its functionality further following this phase. The DSS would benefit from more detailed attention to hydraulics and hydrodynamics as well as a review of the response curves (particularly those for fish) based on monitoring data collected after the commissioning of the Neelum-Jhelum, Patrind, Gulpur, and other planned HPPs.

The summary results of ecosystem and fish integrity presented in the main body of this report tell a forbidding story on biodiversity protection in the Jhelum-Poonch Basin if the full suite of planned HPPs is implemented. More detailed indicator results in Annex G.A of **Annex G** show that it will be extremely difficult, if not impossible, to prevent the loss of fish species under the committed and planned scenarios.

The response curves underpinning the DSS are the result of considerable discussion and review of international literature. They represent the best estimate of the relationships driving the system given current knowledge. They can be used as a foundation on which to build future work to add knowledge on the river ecosystem of the Jhelum-Poonch Basin. Further tests can be done on relationships deemed most influential or least known, such as fish-migration patterns following the fragmentation of the main stem and subsequent use of the nullahs as well as ecosystem responses to the releases of peaking power.

6.1.2 Impact on Subsistence and Recreational Fishing

As described in **section 4**, subsistence fishing is limited and fish is not an important or significant part of local diet. Recreational fishing, however, is important in the Poonch River (mainly the mahseer) and the Neelum River, where the brown trout is found. Communities have shifted to farming rainbow trout in the Kunhar River, so angling of this fish is no longer of significance. In the Poonch River, a community-based program for recreational fishing has been approved by the government and is being implemented in collaboration with the Himalayan Wildlife Foundation. Such initiatives can be replicated in the Neelum River in the areas upstream of Dudhnial, where the brown trout is found (**section 8.5.1**).

6.2 Impacts of Reservoirs on Fish Species of Concern

DRIFT modelling predicts the impact of flow changes on the ecological resources and integrity in the area of management. However, the model does not include impacts from inundation or creation of reservoirs. These impacts are discussed separately in this section.

Most HPPs in the area of management are run-of-river projects and will not result in large reservoirs or impoundments, such as the one created by the Mangla HPP. Nevertheless, reservoirs will be created, where river conditions will change from lotic (moving water) to lentic (still water). The general impacts of reservoirs are summarized in **Annex G**. The impacts of reservoirs on fish species of concern (**section 3.1.3**) in the area of management are summarized below:

- Fish populations are highly dependent on the aquatic habitats supporting their biological functions. Habitat fragmentation caused by HPP reservoirs will reduce the quality and quantity of suitable feeding and spawning grounds for both migratory and resident fish species. Loss of breeding habitats and nurseries will lead to a decline in the populations of certain species, with the possibility of extirpation from the watershed (Rice, Greenwood, and Joyce 2001). Migratory fish are more likely to be affected since they require discrete environmental conditions for the main phases of their life cycle, including reproduction, production of juveniles, growth, and sexual maturation. Construction of a hydropower project, particularly multiple ones on the same river, may result in limitations to their movement and a decline in population numbers, reduction in species diversity, and change in species dominance or natural assemblages (Rice et al. 2008)
- Changes in the physical, chemical, thermal, and geomorphological profile of a river caused by the creation of a dam reservoir often lead to a reduction in fish diversity, change of species dominance or natural assemblies, and impairment for migratory species to fulfill their life cycle.
- In the area of management, most fish species such as *Garra*, *Glyptosternum, Puntius*, *Glyptothorax*, *Shistura*, and *Triplophysa* do not like lacustrine conditions and will likely disappear from the reservoirs. *Schizothorax sp*., particularly the Alwan snow trout, is also likely to abruptly reduce in numbers and become rare. The mahseer is not known to thrive in lake-like conditions. Only the Indus garua finds reservoir conditions favorable and displays colonization in the reservoirs. The expected impacts on fish are summarized below:
    - The three endemic fish species—the Kashmir catfish, Kashmir hillstream loach, and Nalbant's loach—will disappear from the reservoirs as they prefer flowing water and cannot survive in lacustrine conditions.
    - The mahseer requires flowing water for breeding and feeding. While some mahseer are likely to survive in reservoirs, those reservoirs with fine clayey bed sediments (devoid of gravel or cobbles) and a very low current will not provide a preferred habitat for these fish.
    - The population of the Alwan snow trout will dramatically decline in reservoirs as the barrier created by the dam will hinder its migratory patterns.
    - The Pakistani labeo requires a lotic river habitat for breeding and its population is likely to decline dramatically in reservoirs.
    - The Indus garua is an exception as it can adapt to a lentic environment and has better tolerance of temperature variations than other migratory fish species. A loss in its population due to the barrier created by HPPs will likely be offset by an increased availability of habitats in reservoirs.
    - The sucker head is adapted to river conditions. It is not known to breed or feed in reservoirs, so its population will be very small.
    - The twin-banded loach, Himalayan catfish, and Chirruh snow trout will most likely be completely wiped out from the reservoirs.
    - The Gora chela can survive in reservoirs, but its natural population is restricted to the Mangla Reservoir and the lower reaches of the Jhelum River. It will be absent from the reservoirs of HPPs in the upper reaches of the Jhelum.
- A shift in habitat from riverine to lake will open gates for project owners to stock and grow fish for recreational purposes. The slow-moving waters and temperature changes caused by reservoirs can provide improved environments for warmwater fish, such as exotic commercial carp.
- Introduction of exotics such as the grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), common carp, and Mozambique tilapia (*Oreochromis mossambicus*) have already permanently altered the river ecology both upstream and downstream of the Mangla Reservoir. Biodiversity will decrease because of the construction of dams sequentially upstream into the Jhelum River, which will further extend the lake ecosystems into the basin. Fish like the Pakistani labeo and Indus garua, which mainly live in downstream sections of the river, will not be able to swim upstream of the dams because of the construction of the Azad Pattan, Karot, Kohala, and Mahl HPPs. Similarly, fish that mainly breed in warmer waters in tributaries and rivers downstream of the Line of Control, such as the mahseer, Indus garua, and Pakistan labeo, will be unable to travel to the upper reaches of the Jhelum River. The introduction of non-native or introduced fish species in the reservoirs of the planned HPPs can further complicate the situation because of competition for food and resources.

6.3 Impact on Terrestrial Ecology

The construction and operation of hydropower projects in the area of management are likely to impact terrestrial ecological resources because of:

- Habitat loss due to the development of project infrastructure, construction-related activities, and operation of HPPs, although these impacts are restricted to the project sites and vicinity

- Construction and operation of electricity-transmission lines from the HPPs to the grid and onward to consumers

6.3.1 Impacts at Project Site and Vicinity

Terrestrial Habitat Loss

Site clearance and construction of project infrastructures such as the powerhouses, dams, and the inlets and outlets of the tunnels will result in immediate and direct modification of land and loss of terrestrial habitats. This will lead to loss of plants and displacement of animals in the area. Land within the footprint of specific project facilities and its ancillaries will be permanently modified, but the loss will be less severe in the areas lying adjacent to and immediately outside the project facilities.

Once a project begins operations, some terrestrial areas will become submerged because of the formation of a reservoir upstream of the dams. The submerged terrestrial habitat will be converted into an aquatic habitat. The habitat loss and fragmentation resulting from project infrastructure will lead to displacement of terrestrial species.

Impacts on Terrestrial Biodiversity from Construction and Operation

Construction and operation of HPPs cause disturbances to the terrestrial flora and fauna in the impact zone around the project facilities because of blasting, noise, vibrations, illumination, and possible introduction of alien species. Vehicles and machinery, spillage of fuels or chemicals, emissions, and noise will aggravate pollution. Vehicle movements will increase the risk of vehicle collision with wildlife. Biodiversity may also be disturbed because of loss of soil productivity caused by contamination from oil spills and leakages from project vehicles and machinery, uncontrolled discharge of wastewater, and stormwater runoff from the project site.

As plant operation will be continuous, the disturbances will affect both diurnal and nocturnal wildlife. These sensory disturbances and habitat fragmentation may reduce species abundance and possibly change species diversity within an impact zone around each hydropower project in the area of management. The spatial and temporal distribution of species may also be affected. Illegal hunting, fishing, and tree-cutting may also increase as a result of an influx of project staff and contractors.

6.3.2 Impacts on Terrestrial Biodiversity from Transmission Lines

A transmission line is a pair of electrical conductors carrying an electrical signal from one place to another. Several transmission lines will be laid in the area of management to transmit electricity from the newly constructed hydropower projects to the grid and onward to consumers. The general impacts of transmission lines on terrestrial ecology are outlined in **Annex G.**

Figure 14 shows a map of the existing and planned transmission lines overlaid on identified sensitive and protected areas in the area of management based on information taken from "National Transmission and Dispatch Company (NTDC), Pakistan, Existing and Proposed 500/220 kV stations and transmission lines—Grid Map 2020."

Impacts of Transmission Lines in the Area of Management

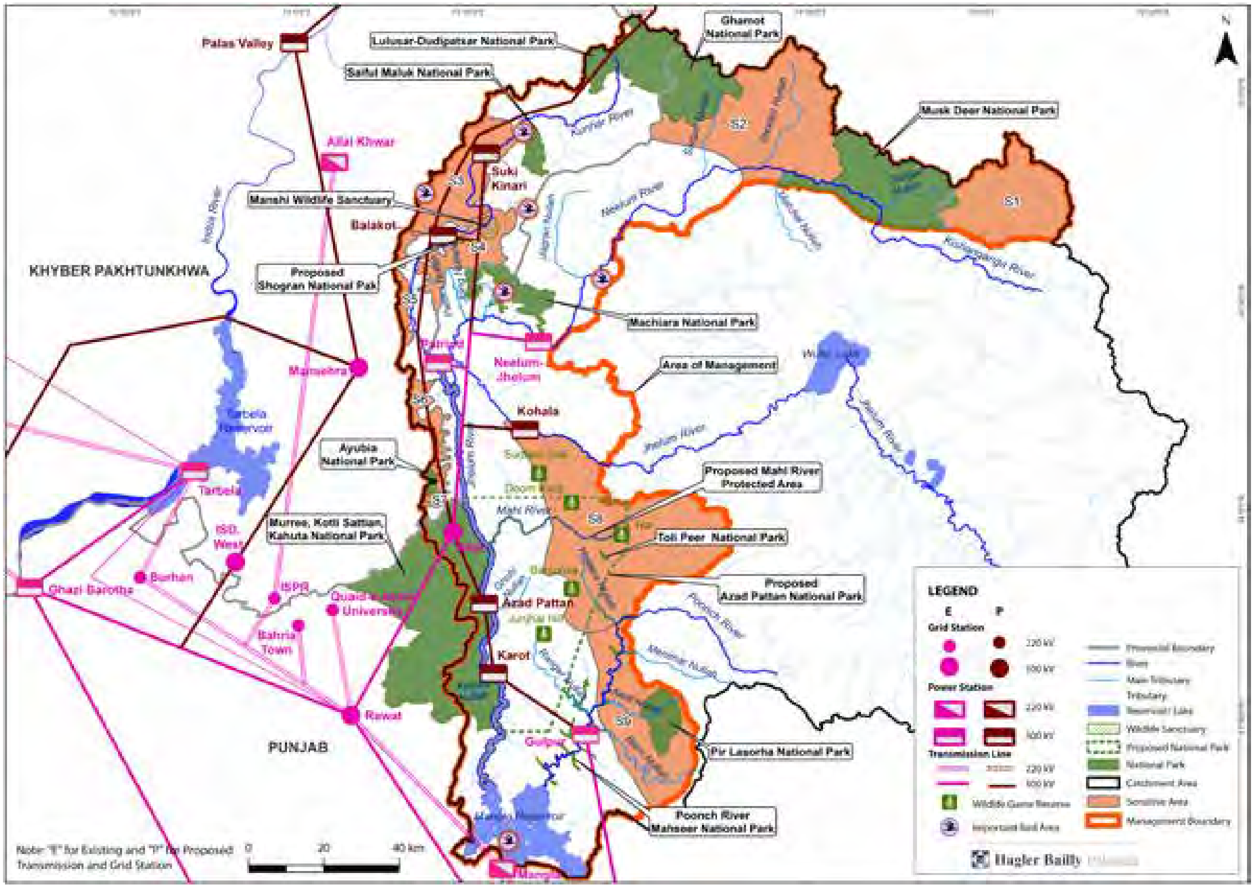
Impacts from the construction and operation of transmission lines on terrestrial biodiversity in the area of management, including sensitive and protected areas identified in **section 3.2.2**, are outlined below:

- Vegetation species will reduce where pylons are erected, leading to localized habitat degradation. The impact of vegetation removal will be high in AJK and some parts of KP, where large tree species (*Pinus wallichiana, Betula utilis, Cedrus deodara, and Pinus roxburghii*) provide quality habitats, breeding sites, and shelters for threatened wildlife species. Sensitive areas S3, S4, S5, S6, and S7 are most vulnerable to this impact.
- Alien-invasive species have been reported from the entire area of management. Habitat disturbance as a result of construction may increase the spread of these species (IFC 2007).
- Construction of pylons will disturb small mammals and herpetofauna, particularly in sensitive areas S3, S4, S5, S6, and S7.
- Sensitive and protected areas in the area of management provide habitats for several large mammals of conservation importance, including the musk deer (*Moschus chrysogaster*), snow leopard (*Panthera uncia*), common leopard (*Panthera pardus*), Asiatic black bear (*Ursus thibetinus*), and brown bear (*Ursus arctos*). Construction-related noise, vibrations, gaseous emissions, and habitat disturbances will drive away these medium to large mammals.
- Birds are most vulnerable to the operational impacts of transmission lines because of possible collision and electrocution. This is of particular

concern in the close vicinity of important bird areas, particularly in sensitive areas S3, S4, and S9. The large raptor species such as the white-rumped vulture, Egyptian vulture, Himalayan griffon vulture, and steppe eagle are most vulnerable to this impact.

- Pakistan is on the Indus Flyway, or International Migratory Bird Route. A significant number of migratory birds visit Pakistan from Europe, Central Asian states, and India, spending winter in various wetlands and deserts, including the high Himalayas, coastal mangroves, and mud flats in the Indus Delta. They return to their native lands at the advent of spring. Based on regular bird counts at different Pakistani wetlands, an estimated 700,000 to 1.2 million birds arrive in Pakistan through the Indus Flyway every year (MoE 2012). Several migratory birds (cranes, ducks, geese, grebes, storks, and ibis) have been reported from the area of management. They are at risk of collision with and electrocution by transmission lines, particularly in close vicinity of the Machiara National Park near Muzaffarabad, important bird areas, and sensitive areas S3, S4, and S9.

Figure 14: Existing and Planned Transmission Lines in the Area of Management until 2020



7. LESSONS LEARNED

Many lessons were learned from the planning, construction, and implementation of hydropower projects in the Jhelum-Poonch Basin between 2015 and 2020. These lessons can inform current and future hydropower development and are summarized in this section.

Recommendations for government departments and hydropower projects outlined in **sections** 8 and 9 are based on these lessons learned, studies carried out for developing this strategy, and consultations with a wide range of stakeholders.

7.1 Conceptual Design and Prefeasibility Stage

The conceptual design and prefeasibility stage has elapsed in the Jhelum-Poonch Basin for all practical purposes. Surveys were conducted by the Water and Power Development Authority (WAPDA) and other agencies as far back as the 1980s and 1990s to identify potential locations of hydropower projects, their basic design (run of river or storage), and capacity (see **Figure 3**). Sustainability issues of hydropower projects and environmental resources were not well understood at the time, and assessments were typically conducted by engineers who examined the technical and engineering aspects only. A process of development was set in motion, which included attracting private capital from independent power producers and requesting public funds for projects the government institutions were interested in developing.

Given this approach, environmental and social issues were not given early consideration in the decision-making to undertake sustainable hydropower development. For example, the Private Power and Infrastructure Board (PPIB) offered HPPs to the private sector after 2000; four HPPs were identified on the Poonch River in a cascade; if fully developed, they would have brought irreversible harm to the river's unique ecosystem, according to the cumulative impact assessment of the Gulpur HPP (HBP 2014). Eventually, only the Gulpur HPP materialized after private developers and other stakeholders spent considerable efforts in resolving conflicts between development and environmental and biodiversity conservation.

A good understanding of the environmental and social resources of the planned development areas is important at all stages. Commencing a project and assuming all environmental and social issues will be resolved often results in inefficient and inappropriate development. Information on the environmental and social resources of the development areas should be documented and shared with all stakeholders, including the government (environmental and electricity regulators as well as development agencies), international lenders, private developers, conservation and academic organizations, and civil society.

Strategic environmental assessments (SEAs) are studies performed at an early stage of development taking a basin-wide approach to environmental management. An example in Pakistan is the *SEA of Hydropower Development in Azad Jammu and Kashmir* prepared by IUCN (Annandale and HBP 2014), which was helpful but commissioned at a fairly late stage. Hydropower development in the Jhelum-Poonch Basin was initiated following the signing of the Indus Waters Treaty of 1960 and the construction of the Mangla Dam. As a development proceeds, an SEA should be updated through independent research, cumulative impact assessments, and ESIAs of individual HPPs. IFC has invested in updating basin-wide baselines under its E&S Hydro Advisory Program to promote sustainable hydropower development in the Jhelum-Poonch Basin. The IUCN SEA (Annandale and HBP 2014) can be updated using the data collected as part of the ESIAs and monitoring of hydropower projects and lessons learned as outlined in this section. Its scope can be expanded to cover Khyber Pakhtunkhwa and focus more sharply on subbasins such as Kunhar where more developments are planned. The sustainable hydropower development strategy outlined in this report can guide hydropower planners and environmental regulators on how to revise the SEA.

A key question remains: who should be responsible for SEAs? Neither public nor private project developers have the mandate, capacity, or resources to prepare them. The process must be institutionalized if long-term sustainability of the basin is to be ensured. Responsibility can be assigned to planning departments with the mandate to prepare development plans and access to information from other departments. The environmental protection agencies (EPAs) can advise the planning departments on technical aspects of SEAs, such as environmental sensitives of areas in which projects are proposed and the types of project design needed for managing environmental impacts. The EPAs can also advise developers on the financial implications of environmental management so that additional costs are recognized at the planning stage and can be recovered through electricity tariffs without compromising the return on investment. Government planning departments, such as the Pakhtunkhwa Energy Development Authority (PEDO) and AJK Power Development Organization (AJKPDO), can work across administrative boundaries and prepare a basin master plan for hydropower prior to approval of HPPs in a basin.

7.2
Feasibility and the ESIA Stage

7.2.1
ESIA Timing in Project Development

Developers have already committed significant financial resources at a project feasibility stage. The PPIB's previous practice was to accept a "chapter on environment" at this early stage, with the expectation that an ESIA will be developed at the detailed engineering and design stage. This approach has since been abandoned by both PPIB and PEDO after serious issues emerged during the commissioning of the Neelum-Jhelum HPP in 2018 when Muzaffarabad residents complained of low flows in the Neelum River. The authorities now require an ESIA to be performed together with a feasibility study and making strong linkages between the two.

7.2.2
Role of Power Purchaser and Electricity Regulator in Environmental Management

The roles of the Central Power Purchasing Agency Guarantee Ltd. (CPPAG) as the power purchaser and NEPRA as the electricity regulator are critical to environmental design and project performance. CPPAG, established in 2015, is an independent organization that reviews project costs and electricity tariffs to be paid to the owner. The tariff is largely determined by the project cost under a policy that allows for cost recovery with an assumed rate of return on capital. However, both the policy and its actual practice have not been clear. Typically, planting trees to compensate for the loss of trees due to construction is accepted as an environmental cost. The practice of investing in offsets to compensate for biodiversity loss is fairly new in Pakistan. Awareness building on the environmental aspects of projects is needed, including the need to view environmental costs as legitimate project costs as well as considering special aspects of hydropower operations, such as the impacts of operating powerhouses in peaking mode for projects in sensitive river environments.

By law, NEPRA requires attention to the environment in developing the power sector. While the governing legislation does not provide details, NEPRA has approved environmental costs as presented in tariff applications over the last five years. Further raising the awareness of NEPRA staff on this matter would help address emerging concerns in the environmental design of hydropower projects. It is recommended that NEPRA develops a methodology to calculate the cost of mitigating negative environmental impacts of a hydropower project and incorporating it into the electricity tariff.

7.3
The Construction Stage

7.3.1
Restrictions on Fish Migration

Temporary diversion tunnels were built in the Gulpur, Karot, and Neelum-Jhelum HPPs to facilitate construction of the dam on the main river. The velocity of water in diversion tunnels is substantially higher than that in the main river, and hydraulic jumps or falls typically occur at the outlet of tunnels. The diversion period can last up to five years. As was observed in the Gulpur project, a separation of species above and below the dam occurs when fish that prefer cooler water, such as the snow trout, swim downstream during fall to avoid low water temperatures upstream; they, however, cannot swim through the tunnel in spring to access their breeding grounds upstream of the dam. The population of this fish declined downstream of the dam over time, as water temperature in summer tends to exceed the range it is adapted to survive. The reverse happened with the Pakistani labeo: the species prefers warmer water and its population declined upstream of the dam. Construction of gates or restrictions to prevent downstream migration of fish through the tunnels remains an engineering challenge, as bedload sediment in flood flows would break such devices placed in the main river. Further research is needed on how to prevent the migratory fish from going downstream or build diversion tunnels that allow them to swim back upstream as well.

7.3.2
Ensuring Downstream Flow When Diversion Tunnels Are Sealed for Impoundment

Diversion tunnels must be closed at the end of construction to fill up a dam. By design, the concrete slabs must be lowered quickly to block the flow into the tunnels. Unless a provision is made in the design for flow release while the dam is being filled (impoundment), river flow may stop altogether. This situation occurred in the Gulpur Dam: special provisions were carefully engineered to release some flow from the diversion tunnels while the dam was being filled up. The flow was also slowed to give fish downstream of the dam time to swim toward the river center for survival. Over 150 workers were hired and trained by the Himalayan Wildlife Foundation to manually pick up stranded fish and put them back in the flow, minimizing fish mortalities. It is important to think through such contingencies at the design stage to maintain an appropriate level of flow downstream of the dam when the reservoir is filled. The timing and duration of the impoundment are important factors affecting the level of downstream flow.

7.3.3 Sediment Extraction and Dumping

ESIAs of hydropower projects usually restrict the extraction of sediment from a river for use as construction material and prohibit the dumping of excavated waste back into the river. Nevertheless, most HPPs ignore these restrictions sometimes to a significant extent. Extraction and dumping pose negative impacts on the aquatic habitats, particularly in tributaries that serve as important fish breeding areas. The extracted sediment typically includes boulders and cobbles, which are an essential part of riffle habitats as they provide refuge for non-migratory fish and surface for algae growth. The dumped sediment is typically silt and clay, which increases the embeddedness of riffles by settling into spaces between the boulders and cobbles, essentially making the habitat unsuitable for fish adapted to riffle habitats.

Where feasible, HPPs should consider extracting sediment from the stretch of the river that will be inundated by the reservoir when the project is commissioned. The current practice is to extract sediment from nearby tributaries where water levels are low. Extraction of sediment from riverbed will likely involve additional costs, which need to be weighed against the potential ecological damage in tributaries. Monitoring of these practices should be improved: at the moment, independent inspectors engaged by the EPAs or lenders only perform periodic monitoring and developers are often warned to cease extraction and dumping activities while the inspectors are on site. One option is to engage the inspectors to perform continuous monitoring, which has been practiced elsewhere in the country.

7.4 The Operation Stage

At the operation stage, the environmental impacts can be categorized into two groups: those that were anticipated in the ESIAs but present challenges for compliance, and those that were unforeseen and require design and mitigation measures to manage.

7.4.1 Impacts Anticipated in the ESIAs

HPPs and regulators should differentiate between compliance monitoring and impact monitoring. Compliance monitoring, or keeping the operating parameters such as EFlows within prescribed limits, is insufficient, and the adoption of effective mitigation measures should be a continuum. Simply complying with legal standards is often inadequate, particularly when observed impacts reach a level of serious concern for stakeholders and trigger grievances. Biodiversity action or management plans in ESIAs have provisions for adaptive management. Even if these provisions are not specifically stated in the ESIAs, the environmental laws and performance standards of the lending agencies require developers to take responsibility for any impacts caused by the project. Project owners and government regulators should be aware of the need for adaptive management if monitoring results indicate that a project is imposing negative impacts on the ecological conditions of the river and local communities. This could require modifying the environmental management and monitoring plans, making necessary operational changes in commercial agreements, and changing the tariffs for electricity produced if warranted.

7.4.2 Impacts Unforeseen in the ESIAs

Knowledge Gaps and Changing Performance Standards

Some laws and performance standards have been revised and upgraded based on research and better understanding of the impact pathways. HPPs built and financed before 2012 were required to comply with generally less stringent government regulations and environmental and social standards imposed by lenders than those built more recently. For example, IFC Performance Standards (2012) include requirements for the release of EFlows, peaking, and impacts on important biodiversity. This has created conflicts within the Jhelum-Poonch Basin as some HPPs question why they must comply with stricter standards than others in the basin. The EPAs should become aware of such anomalies and ensure that all projects are actively reducing their environmental impacts when performing periodic basin-wide review of HPP performance. The EPAs can conduct such reviews with support from the industry through funds allocated for research and monitoring in their biodiversity action or management plans.

Powerhouse Emergency Shutdowns

A major concern is the accidental or emergency closure of the powerhouse following a fault in the machinery and equipment or control systems. Past events have demonstrated that water has to be drained from the dam to drop the reservoir level when the powerhouse is forced to be shut down. This can create a sudden and unusual rise in the flow and water level in the river downstream of the dam, leading to dispersal of fish. Simultaneously, fish can be trapped in pools left by receding water along the shorelines of the reservoir upstream of the dam. When the release from the dam is suddenly stopped and the reservoir drops to an appropriate level for inspection and maintenance at the powerhouse, the water level in the downstream river falls, leaving fish stranded in the side pools. Fish mortality, particularly among juvenile fish that cannot navigate quickly in changing water levels, can be significant if such an event occurs in summer when both the water and air temperatures are high, exposing fish directly to sunlight.

A sudden increase in water level can be dangerous for people sitting or working near the river. It can also cause damage to equipment and property, such as vehicles brought in to collect sand and gravel from the river. All HPPs must therefore conduct a risk assessment of operations and the likely consequences on the environment and people. Projects should have a standard operating procedure for biodiversity protection and management during emergency or operational failures, including on-site fish rescue equipment, trained personnel, and a warning system.

Control of Invasive Fish Species and Biodiversity Management in Reservoirs

Although several HPPs are the run-of-river type without large storage capacity, reservoirs of different lengths can be created by the projects upstream of the dam or weir. These reservoirs are often managed to develop fish hatcheries for commercial fish. Past experiences in the country have shown that stocking exotic fish in these reservoirs has destroyed the indigenous fish fauna. It is therefore recommended that such reservoirs only be stocked with indigenous and not non-native fish species.

Hatcheries, such as the one at the Mangla Reservoir, were originally developed to breed indigenous fish species. However, commercial considerations have led some to start breeding exotic fish species, which grow faster and have higher food value and more easily available fingerlings or rearings. Exotic species, such as the common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), and bighead carp (*Hypophthalmichthys nobilis*), can fetch 25 percent more revenues than indigenous species when sold for commercial purposes. Such species, however, tend to out-compete native fish species for food, compromising the latter's growth and breeding potential and leading to a gradual decline of their populations and diversity. The Mangla Reservoir has recorded a drop in the population of indigenous fish species, such as thalia (*Catla catla*), after exotic species were introduced. Breeding of exotic species is widespread in the hatcheries, making them an easy option for stocking in the reservoirs.

Even in reservoirs where non-native fish are not stocked, the abundance of some exotic species may increase if the habitat is altered to their liking. Many non-native species, such as the common carp, prefer lake environments similar to reservoirs. Their populations should be monitored and kept in check if they become a threat to native fish species through blocking access to spawning grounds, direct predation, or competition for food and other resources.

The following recommendations can be considered for biodiversity management in the reservoirs:

- Develop a range of research-based strategies and measures that are effective for specific reservoir conditions.
- The reservoirs should not be stocked with exotic (non-native) fish species or fish produced in hatcheries using brood stock from other basins.
- Conduct research on the potential adverse impacts on the genetic health of local fish populations prior to undertaking any stocking program.
- Selective commercial and recreational fish harvesting can be considered.
- Reservoirs will provide a staging ground for local and migratory birds. Hunting or shooting these birds should be prohibited.
- Ban the disposal of solid and liquid waste into the reservoirs from nearby towns. Water quality should be monitored.
- Afforestation in the watershed will prevent soil erosion and siltation of the reservoirs. Therefore, existing trees and bushes should not be cut, and new trees should be planted.
- To enhance community participation and support the local economy, the reservoirs may be developed for recreational activities, such as boating, parasailing, angling, scuba-diving, and snorkeling, after consultation with all stakeholders.
- Build capacity among local fishers and provincial fisheries departments, which manage the stocking of fish in reservoirs. The authorities should monitor HPP reservoirs to ensure that alien species are not introduced.
- Formulate guidelines for managing reservoirs.

Impacts of Transboundary Projects

Environmental flow for the Kishanganga HPP was a principal point of contention between Pakistan and India; it was eventually determined by the Permanent Court of Arbitration at The Hague following presentations made by both countries. The Lower Jhelum and Patrind HPPs set up upstream of the Line of Control on the Jhelum and Poonch rivers, respectively, were designed to operate as peaking plants.

While IFC requires special attention to mitigation measures for projects affecting international waterways (IFC Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts), the country laws in India and Pakistan do not specifically address transboundary impacts. The Kishanganga Dam constructed by India on the Neelum River is an exception, where the award of the Permanent Court of Arbitration under the Indus Waters Treaty has a provision for monitoring impacts of project operations on the environment for seven years, following which the countries can request a revision in the EFlow prescribed by the court. Since the Kishanganga Dam commenced operations, significant mortalities of the Himalayan catfish were observed in the Neelum River and populations of the brown trout have also been in decline. The Parnai HPP, when operating in peaking mode, causes significant variations in flow and temperature in the Mendhar Nullah, a tributary of the Poonch River that flows across the Line of Control from Indian-administered Kashmir into Pakistan-administered Kashmir. These flow variations have negatively affected the fish populations and their breeding in the nullah. Similarly, operation of the Lower Jhelum HPP in peaking mode causes significant variations in flow in the downstream river in Pakistan-administered Kashmir, leading to fish mortalities.

Given the shared rivers in the Indus Basin and the number of projects that have been set up and planned on the rivers, transboundary cooperation and consultation on environmental aspects is important at the design and construction stages of projects. In light of how transboundary environmental concerns were managed for the Kishanganga project, it would be best for the countries to explore options for cooperation through the institutional mechanisms established under the Indus Waters Treaty of 1960 and avail guidance from international best practices.

7.5 The Gulpur Project: Example of Adherence to Best Practices

International development organizations encourage borrowers to adhere to international standards and incorporate environmental and social issues into project design and ESIAs. The Gulpur HPP financed by IFC, ADB, CDC Group, and Korea Exim bank was Pakistan's first hydropower project in which a comprehensive EFlow assessment was conducted. It resulted in modifications in the power plant's design and operating rules and the implementation of a biodiversity action plan. Best practices and knowledge gained through the project have since been incorporated into the ESIAs of other HPPs financed by international lenders. The best practices include the following:

- Review of literature to understand the structure of the river ecosystem and pressures on it as well as degradation trends
- Covering all aspects of the ecosystem and food chain, inclusive of water quality, fish fauna, macroinvertebrates, algae, riparian vegetation, and river-dependent birds and mammals
- Using a combination of site-appropriate techniques and standard operating procedures, combined with supervision and quality control, to ensure the accuracy of baseline data
- Employing qualified and experienced staff and resources to collect data and supervise field work; consultations and review by international experts to fill knowledge gaps
- Collection of ecology-related data over three seasons for at least a year to develop an understanding of the annual life cycle of organisms
- Spatial coverage through the basin to understand the functioning of the ecosystem inclusive of the river and its tributaries
- Documentation of the ecosystem services and local community's dependence on river resources
- Consultations with the community to capture and document local knowledge on the river ecosystem and its functioning
- Continuous engagement with the fisheries and wildlife departments to improve their knowledge base and build relationships with department staff
- Continuing engagement with conservation groups active in the area to understand their perspectives on conservation and management
- Assessment of key biodiversity values followed by a critical habitat assessment
- Implementation of a biodiversity action plan to ensure a net gain of biological values for which the critical habitat is designated
- Cumulative impact assessments of all hydropower projects planned in the basin

The following outcomes were achieved in the Gulpur project following best practices:

- Consultation with the Himalayan Wildlife Foundation, an environmental NGO active in the Poonch Basin, yielded information to notify the river as the Poonch River Mahseer National Park and shed light on the threats faced by the park.
- A relationship was built with the Himalayan Wildlife Foundation and the AJK Fisheries and Wildlife Department to develop a win-win strategy for protection of the national park and environmental management of the project.
- A deeper understanding of the national park's unique resources was developed, including the presence of Critically Endangered Kashmir catfish and a range of migratory fish species.
- The river was identified as a critical habitat guided by IFC's Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources, triggering the need for an offset to achieve net gain for two endemic fish species that triggered the critical-habitat status.
- Leading EFlow practitioners who had experience in conducting assessments for hydropower projects in the Himalayan rivers were engaged to set up the DRIFT model for a holistic EFlow analysis.
- In addition to measuring the impact of alternative EFlow configurations on the river ecosystem, the DRIFT model was enhanced to assess the impact of management measures, such as improved protection and regulation of sediment mining in the river to enhance the populations of fish species.
- A comprehensive biodiversity action plan was prepared and included in the ESIA to integrate biodiversity management into project development and operation.
- A comprehensive cumulative impact assessment was conducted following IFC guidelines and alerted the government to the cumulative impacts from building multiple hydropower projects on the Poonch River. This led to a policy change of banning further development on the river.
- Training was conducted for the Gulpur HPP staff and consultants as well as many AJK, Punjab, and Khyber Pakhtunkhwa government staff.

The development of the Gulpur project is perhaps an exceptional example of applying principles of sustainable development to hydropower amid a challenging setting with limited capacities and resources. The lessons learned and sustainable development approaches from the project have been further refined and applied in the ESIAs of the Azad Pattan, Balakot, Karot, Kohala, and Mahl projects in the basin. Use of scientific EFlow assessment techniques has raised their importance in hydropower development and improved project performance levels at the planning stage. IFC's lead helped overcome significant challenges in the development of the Gulpur project and resulted in a satisfactory outcome.[24]

The Balakot project financed by ADB is also located in a critical habitat. It followed the example set by the Gulpur project and included a holistic EFlow assessment and a biodiversity action plan in the ESIA. Developers of the Chakothi-Hattian and Athmuqam HPPs also adopted the Gulpur project's methodologies for collecting river biodiversity data and conducting EFlow modeling. However, these two projects will unlikely be developed in the near future.

7.5.1
Need for Consistency in Applying International Practices

Environmental regulators have often treated the ESIAs submitted by the private sector differently from those submitted by the public sector. An example is the government-owned Neelum-Jhelum project, the construction of which commenced in 2008. When the project became operational a decade later, serious lapses were observed with respect to environmental flows and impacts on community assets, such as springs and houses. Adjustments to EFlow release from the dam as approved in the project ESIA were made only after downstream Muzaffarabad residents started protesting inadequate flows in the Neelum River.[25] The project's EFlow was later enhanced on the direction of the AJK High Court to address the residents' concerns. The government has now cleared the project for implementation after reaching a consensus with stakeholders on the project's environmental design.

Another government-owned project is the Balakot HPP being developed by PEDO and financed by ADB. While the ESIA of the Balakot project on the Kunhar River included a biodiversity action plan to address concerns triggered by the river's classification as a critical habitat following IFC Performance Standard 6, several other projects on the same river do not address the environmental concerns to the same level. To ensure consistency among HPPs in the basin, it is important to build awareness and capacity among the

[24] IFC video: https://www.youtube.com/watch?v=7owoqAm4oYg

[25] The Environmental Impact Assessment (EIA) determined EFlow release of 9 m³/s at the dam. With an expected addition of 6 m³/s from a tributary immediately downstream of the dam, a flow of 15 m³/s was anticipated at the city of Muzaffarabad further downstream. Subsequently, to respond to stakeholder concerns, the EFlow at the dam was increased to achieve a total minimum flow of about 30 m³/s at Muzaffarabad.

Khyber Pakhtunkhwa EPA and PEDO to adopt best practices that have been included in the ESIAs of the Gulpur and Balakot projects for other projects in the province.

EPAs should be more proactive in maintaining consistent standards for environmental assessment and performance irrespective of project ownership of the project. EPAs should also make it mandatory for hydropower developers to follow international good practice guidelines.

7.5.2 Need for Adaptive Management to Address Emerging Environmental Concerns

Following the protests by Muzaffarabad residents against the impact of low flows in the Neelum River, an EFlow of 30 m^3/s approved by the Azad Jammu and Kashmir Environmental Protection Agency (AJKEPA) for the Kohala project came into question. The government and stakeholders also set forth a requirement for additional mitigation measures, such as construction of ponds in the Jhelum River in the low-flow section downstream of the dam for recreational and aesthetic purposes as well as setting up wastewater treatment plants in Muzaffarabad to counter the impact of lower levels of wastewater dilution at the city. The construction of the Kohala project was delayed for more than a year until an agreement to fulfill these demands was reached in 2019, subject to their technical feasibility. An increased awareness of environmental protection among local communities created pressure to implement mitigation measures that went over and above those envisaged in the ESIAs of the Neelum-Jhelum and Kohala projects approved by the AJKEPA. It is important that EPAs and project developers understand the need for adaptive management in both project ESIAs and environmental regulations to address emerging concerns, create consensus through forums, and resolve the issues based on informed decisions.

7.6 Summary of Lessons Learned and Recommendations

Table 13 provides a summary of the lessons learned and recommendations, which are also outlined in **sections 8** and **9**.

Table 13: Lessons Learned and Recommendations

Topic	Lessons learned	Recommendation
Conceptual design and prefeasibility	An update of the SEA for hydropower development in AJK prepared by IUCN will help stakeholders identify impacts and plan for mitigation early.	• Require SEA based on sound research and data that is shared with stakeholders before approving HPPs in a basin. The 2014 IUCN SEA should be updated with the data collected as part of the ESIAs and monitoring of projects as well as lessons learned. Its scope can be expanded to cover Khyber Pakhtunkhwa and focus more sharply on subbasins such as Kunhar where more developments are planned. The sustainable hydropower development strategy outlined in this report can guide hydropower planners and environmental regulators on how to revise the SEA. • Government planning departments, such as PEDO and AJKPDO, can work across administrative boundaries and prepare a basin master plan for hydropower prior to approval of HPPs in a basin. This will help the departments and project developers identify environmental costs at an early stage of development and include them into project costs so that they can be recovered through electricity tariffs without compromising the return on investment. The EPAs can provide guidance on technical aspects of SEAs. • PEDO and provincial EPAs have jurisdiction limited to their territories. Identification of an umbrella organization to perform coordination between these jurisdictions may also be considered.
Timing of environmental and social impact assessment (ESIA) in project development	ESIAs need to be completed prior to government approval of projects.	• These ESIAs should be performed together with a feasibility study of a project. It needs to be reviewed and approved by relevant government agencies before project approval is given.

Topic	Lessons learned	Recommendation
Effectiveness of environmental regulation	EPAs can help the public sector improve environmental design and performance of projects drawing on good practices adopted by the private sector.	• EPAs should promote good practices adopted by private-sector projects among the public sector. • EPAs should encourage developers to adopt good practice guidelines, such as IFC's handbooks for EFlows and cumulative impact assessments.
Role of power purchaser and electricity regulator	Environmental costs should be identified, accounted for in project budgets, and included in tariff calculations.	• Information on the importance of environmental costs and their inclusion in tariffs should be shared and discussed with relevant agencies. • Regulators should consider environmental costs an integral part of project costs and devise a consistent methodology that ensures their inclusion in project costs. • Developers should ensure that environmental costs are included in project budgets, the engineering, procurement, and construction stage, as well as operations and maintenance contracts. • HPPs and lenders should continue to engage and educate NEPRA staff to address emerging concerns in environmental design of hydropower projects, such as avoidance of peaking and operation of projects at baseload in sensitive river environments.
Role of owners of projects financed by international lenders	The Gulpur HPP provides application examples of high environmental and social standards set by international lenders, including the use of EFlow modeling.	• The lessons learned from the Gulpur HPP development process as well as other internationally funded projects should be shared with other HPPs as examples of good practice that will promote sustainable hydropower. This can be carried out through the Hydropower Developers' Working Group to reach the private sector.
Role of owners of projects financed by other lenders	Environmental requirements should be consistent across HPPs.	• To ensure consistency among HPPs in the basin, government agencies should review and promote the same level of good international practices in the ESIAs of all projects. Capacity building for government agencies on good ESIA practices would be helpful.
Setting EFlows	EFlow levels should be set after a full assessment of the impacts.	• Government regulators should encourage developers to adopt robust EFlow assessment methodologies in the early stages of ESIAs to assess potential impacts and determine adequate EFlow levels. Inadequate EFlow assessment can lead to negative impacts on the communities and aquatic ecosystems.
Construction stage: restrictions to fish migration	Fish may be stranded downstream of HPP damsites during construction.	• HPPs should assess and adopt techniques to prevent migratory fish from going downstream through diversion tunnels or construct tunnels where fish can swim back upstream as well. Research on such techniques is needed.
Construction stage: sealing of diversion tunnels	Impoundment or the commissioning of a reservoir needs to consider downstream impacts.	• HPPs should develop an impoundment/commissioning plan that considers impacts on downstream aquatic ecosystems and people. EPAs should require this plan as part of the ESIA.
Construction stage: extraction of sediment from and dumping in rivers	The collection of sand and gravel as well as the dumping of sediment need additional regulation.	• Third-party inspectors should be hired by the EPAs and lenders to ensure that HPP construction materials are not taken from the riverbed and sediments are not dumped into the river.
Operation stage: monitoring and adaptive management	HPPs should monitor indicators to evaluate project impacts over time, implement adaptive management if negative impacts are detected, and adopt emerging best practices where feasible.	• HPP developers, environmental and electricity regulators, and power purchasers should be made aware of: 1) the need for regular monitoring of environmental indicators to evaluate impacts on local communities and river ecology, 2) adaptive management if monitoring results indicate that the project is imposing negative impacts on social or ecological conditions of the river, and 3) the need to monitor environmental management and monitoring plans and to allow for operational changes in commercial agreements to improve environmental performance. • EPAs can hold periodic review sessions with senior management of HPPs to share emerging best practices in environmental management, mitigation, and monitoring.

Topic	Lessons learned	Recommendation
Operations stage: emergency shutdown of powerhouse	HPPs should be prepared in case of emergency stoppage to prevent downstream impacts.	• Developers should develop a standard operating procedure in case of emergency stoppage of water flow. EPAs and lenders should require this procedure as part of the ESIA.
Operations stage: control of invasive fish species in reservoirs	Reservoirs must be managed.	• Stocking reservoirs with exotic species should be strictly banned. Based on research, a range of strategies and measures can be effective in the specific reservoir conditions, such as selective commercial and recreational harvesting, combined with capacity building of managers and local fishers in control of invasive species.
Design and operations stage: transboundary projects	Transboundary impacts of HPPs should be assessed in ESIAs.	• Transboundary cooperation and consultation on environmental aspects is needed at the design and operations stages of projects. Transboundary impacts could be given consideration in the ESIA.

8. RECOMMENDATIONS FOR GOVERNMENT

The previous sections give an overview of the ecological resources and socio-economic conditions of the Jhelum-Poonch Basin followed by an assessment of impacts from the construction and operation of hydropower projects in the basin. This section provides recommendations for the government to minimize the negative impacts of HPPs in the basin. In essence, this section and the next comprise the strategy for promoting sustainable hydropower development in the basin.

The recommendations outlined in this section are listed in order of importance based on a prioritization survey of participants at a stakeholder meeting organized by IFC in January 2019 (**section 1.6**).

8.1 Prepare and Implement Guidelines for EFlow Assessments

Hydropower projects and other river structures change the downstream flow patterns, consequently affecting water quality, temperature, sediment movement and deposition, fish and wildlife, and the livelihoods of people who depend on healthy river ecosystems. Environmental flows (EFlows) describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems as well as the human livelihoods and well-being of all living organisms that depend on ecosystems. Through the implementation of EFlows, water managers strive to achieve a flow regime or pattern that provides for human use and maintains processes required to support healthy river ecosystems (Postel and Richter 2003).

Provincial EPAs are recommended to develop guidelines for selecting the appropriate EFlows in hydropower projects that are in line with the principles outlined in the World Bank Group's *Good Practice Handbook* (WBG 2018). This handbook provides guidance to practitioners on taking rigorous and consistent approaches to assess and manage HPP impacts on downstream river ecosystems and people through EFlow assessment and provision.

The specific approach outlined in the handbook can be summarized as follows:

- Understand the context of river functioning and the provision of ecosystem values and services where EFlows will be introduced.
- Understand the potential downstream impacts associated with hydropower development and how these can be mitigated.
- Understand the information provided by EFlow assessments.
- Apply a context-appropriate EFlow assessment method.
- Conduct a comprehensive stakeholder engagement program that leads to a decision on EFlows and other mitigation measures based on the outcome of the assessment.
- Compile an EFlow management plan.

The handbook draws on the lessons and experiences of IFC, the World Bank Group, and its clients. It aims to provide additional good practice guidance in support of IFC's Performance Standards on environmental and social sustainability and the World Bank's Environmental and Social Standards.

Section 7.4 summarizes some of the negative impacts during operation of hydropower projects. This may include an emergency shutdown of turbines or powerhouse and subsequent stoppage or reduction in flow to the downstream river reaches, creating negative impacts on people and aquatic ecosystems downstream.

Recommendation 1: Provincial EPAs should develop guidelines for hydropower projects to select and maintain appropriate EFlow in line with WBG principles (WBG 2018). Case studies in the WBG handbook, such as the selection of EFlow for the Gulpur HPP, can be referred to as appropriate. In addition, EPAs should also develop guidelines and standard operating procedures for addressing emergency shutdown during project operations and require them to be included in the ESIA.

8.2
Regulatory and Policy Reform

8.2.1
Requirement for Environmental Impact Assessment and Initial Environmental Examination

The Pakistan Environmental Protection Agency Review of Initial Environmental Examination and Environmental Impact Assessment Regulations 2000 (IEE-EIA Regulations) provide the necessary details on the preparation, submission, and review of an initial environmental examination (IEE) or environmental impact assessment (EIA). This delineation is based on the GOP's Policy and Procedures for the Filing, Review and Approval of Environmental Assessments 1997. According to this policy, HPPs with over 50 megawatts (MW) fall in Schedule II and require an EIA, while those with less than 50 MW fall in Schedule I and require only an IEE. This regulation has been adopted as:

- The Azad Jammu and Kashmir Environmental Protection Agency Review of Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) Regulation 2009 in the state of AJK
- The Punjab Environmental Protection Act 1997 (Amended 2012) in Punjab province
- Khyber Pakhtunkhwa Environmental Protection Act 2014 in KP province

As outlined in **sections 3** and **4**, different sections of the rivers differ in their sensitivity to hydropower development. Therefore, using the 50 MW generation capacity figure as the main determinant of environmental-assessment standard is misguided. HPPs with capacities less than 50 MW but within ecologically and socio-economically sensitive zones do not necessarily exhibit fewer environmental issues; the limited scope of an IEE can also fail to gauge and manage the potential individual and cumulative impacts of these projects. It is therefore recommended that the 50 MW benchmark should not be the main screening criterion used to determine the required level of environmental assessment. The ecological- and social-sensitivity ranking tables and maps outlined in **sections 3** and **4** must also be taken into consideration.

The state and provincial regulations for AJK, Punjab, and KP should be amended so that all energy projects, even if they are less than 50 MW, should require an environmental and social impact assessment (ESIA) if they are located in a highly sensitive ecological or socio-economic zone (**sections 3** and **4**).

Schedule I of the IEE-EIA Regulations should be rewritten as follows (with additions in bold):

Schedule I: List of Projects Requiring an IEE

B. Energy

1. Hydroelectric power generation less than 50 MW. **Projects under 50 MW qualify for an IEE unless they are located in a highly sensitive ecological and/or social segment, in which case they must undergo a full EIA.**

Recommendation 2: The state and provincial environmental protection regulations in AJK, Punjab, and KP should be amended to require EIAs for hydropower projects that have a capacity of less than 50 MW but are located in highly sensitive ecological or socio-economic zones.

8.2.2
Sediment Mining from Riverbed and Banks

Illegal and unregulated mining of river sediment—such as sand, gravel, and boulders—from the riverbed and riverbanks presents a serious threat to the aquatic life of the river, particularly fish of conservation importance. The owners of the Gulpur HPP are supporting the preparation of a sediment mining and management plan for the Poonch Basin in AJK, which includes an assessment of existing policies, laws, and regulatory practices for mining activities. Recommendations for improvements in these regulations are also provided to facilitate the implementation of a sustainable mining plan in the Poonch River (HBP 2020). A summary of these recommendations is provided in **Table 14**. While these were developed primarily for the Poonch River, which is a national park in AJK, similar recommendations can be developed for Punjab and KP.

Recommendation 3: Amend policies, laws, and regulations to promote sustainable sediment mining from riverbed and banks. The basic principles to be followed will include protection of sensitive river habitats by restricting extent and type of mining to less sensitive areas to meet basic community needs and to protect livelihoods of poor and vulnerable mining communities.

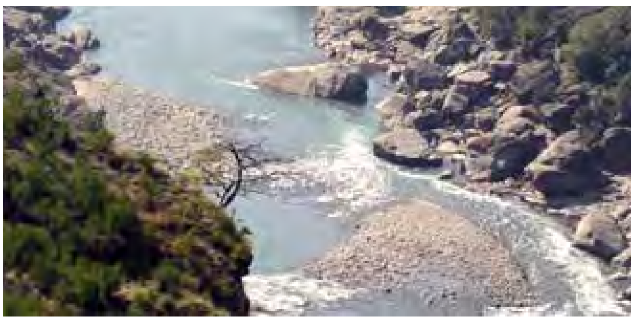


Table 14: Summary of Recommendations for Regulatory Reform to Promote Sustainable Mining

No.	Provision in the law	Issues, status of compliance, and gaps	Recommendations
Azad Jammu and Kashmir Mining Concession Rules, 2002			
1.	Mining can only be done after the assignment of a mining lease and grant of a mining permit by the Mines and Minerals Department.	• The department has not issued any mining permit in the Poonch River over the last two years. • No records of quantities extracted and royalties paid are publicly available. • Some mining operations are near settlements and roads.	• The department should prohibit illegal mining in a national park. • Impose heavy penalties and fines on violators or even revoke their mining permits. • The record of permits, quantities extracted, and royalties paid should be publicly available. • The mining operations located near settlements should take appropriate health and safety measures.
Azad Jammu and Kashmir Minor Mineral Concession Rules, 1994			
2.	Mining can only be done after assignment of a mining lease and grant of a mining permit by the Mines and Minerals Department.	• The department has not issued any mining permit in the Poonch River over the last two years. • No records of quantities extracted and royalties paid are publicly available. • The royalties as specified in the AJK Minor Mineral Concession Rules, 1994 are outdated and bear no relationship to the market value of the materials extracted by miners from the river.	• The department should prohibit illegal mining in a national park. • The mining rules should be amended to allow mining in protected and ecologically sensitive areas, including rivers and protected forests, under certain conditions.
Azad Jammu and Kashmir Wildlife (Protection, Preservation and Management) Act, 2014			
3.	Mining is not permitted in national parks. Exceptions can be made if it can be established that a mining project will contribute to betterment of the park, or if mining can provide incentives to communities for park management under the framework of sustainable development.	• Ongoing mining in the Poonch River does not conform to the requirements of the law. Sustainability has been completely ignored by the mining regulator, miners, and the mining industry.	Opportunities for sustainable mining exist, but extraction needs to be limited based on scientific studies of sediment availability and ecological impacts of extraction. • Commercial mining of deposits of bedload sediment can be allowed at the upstream end of the Gulpur HPP reservoir under the existing regulations for mining, modified as recommended in this study. • Azad Jammu and Kashmir Fisheries and Wildlife Department (AJKFWD) and Azad Jammu Kashmir Environmental Protection Agency (AJKEPA) should have a representative in the Auction Committee under the Minor Mineral Concession Rules, 1994, where leases are to be awarded in sensitive and protected areas. • Revenues from commercial mining should be shared with AJKFWD so investments can be made for the betterment of the national park as well as local communities and development activities in the park. A sharing ratio of 80:20 is recommended between AJKFWD and the Mines and Minerals Department. • Community-based mining of sand and gravel can be managed by AJKFWD in coordination with local community organizations recognized by the department with revenue sharing arrangements. A sharing ratio of 80:20 is recommended between the community and AJKFWD, adopting the approach for trophy hunting in Pakistan. • All mining in the national park will be subject to approval of EIA by AJKEPA.

No.	Provision in the law	Issues, status of compliance, and gaps	Recommendations
Azad Jammu and Kashmir Environmental Protection Act, 2000			
4.	• Proponents of a mining project need to submit an EIA and obtain approval from AJKEPA before commencing mining. • Environmental monitoring reports need to be submitted periodically after a project commences.	• No EIA has been developed by miners and approved by AJKEPA before the start of mining activities in the Poonch River Mahseer National Park. • There is no monitoring of mining activities and their impact on the environment. • Where notices to shut down mining activities are issued by AJKEPA, follow-up enforcement by the district administration remains limited.	• AJKFWD, the Mines and Minerals Department, and the district administration should not permit mining in the national park without prior regulatory approvals, including the EIA and monitoring as specified in approvals. • AJKEPA should issue guidelines for preparation of EIAs and IEEs for mining, with special attention to mining in sensitive and protected areas. • AJKFWD and AJKEPA should have a representative in the Auction Committee under the Minor Mineral Concession Rules, 1994.
Azad Jammu and Kashmir Forest Policy and Legislation			
5.	• Mining can only be carried out in forest land with the consent of the Forest Department. • All types of forest produce, including non-timber forest products, are to be regulated and managed by the Forest Department under authority given by the Azad Jammu and Kashmir Minor Mineral Concession Rules, 1994.	• Mining of bedload sediment, including boulders and stones, needs to be partially or completely shifted from the Poonch River to forest land in the Nakiyal Hills, where limestone deposits are available. • The Forest Department is neither collecting revenues nor exercising control over mining activities in forest land. • Lack of environmental management and control of mining in forest land means that shifting mining from the Poonch River to forest land in Nakiyal Hills will result in shifting impacts from one sensitive area to another.	• As recommended for mining of bedload sediment in the Poonch River, the Forest Department should regulate and control mining activities in forest land and collect revenues from it.

8.3 Protected Areas

A protected area is "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (IUCN 2008)." In light of the construction of multiple hydropower projects in the area of management, it is important to conserve existing protected areas and designate new ones to offset the loss of ecological resources.

8.3.1 Conservation of Aquatic Protected Areas

The only aquatic protected area in the area of management is the Poonch River Mahseer National Park. The entire stretch of the Poonch River, along with its tributaries, was declared "River Poonch Mahseer National Park" in an official notification from the AJK government.[26]

The Poonch River has high fish diversity (38 fish species) and provides habitats to fish of both conservation and economic importance, particularly the Endangered mahseer (*Tor putitora*). The mahseer's

[26] Government of the State of Azad Jammu and Kashmir, Secretariat Forest/Azad Kashmir Logging and Sawmills Corp. (AKLASC)/Fisheries, Official Letter for Notification of River Poonch and Tributaries as Protected Area, December 15, 2010, Ref no: SF/AV 11358-7/2010.

population has undergone a dramatic decline over the last few years. The Poonch River provides a breeding ground for the mahseer and has the largest stable population of the fish in the country. The river also provides habitats for the Critically Endangered Kashmir catfish and a breeding ground for commercially important fish species of the Mangla Reservoir.

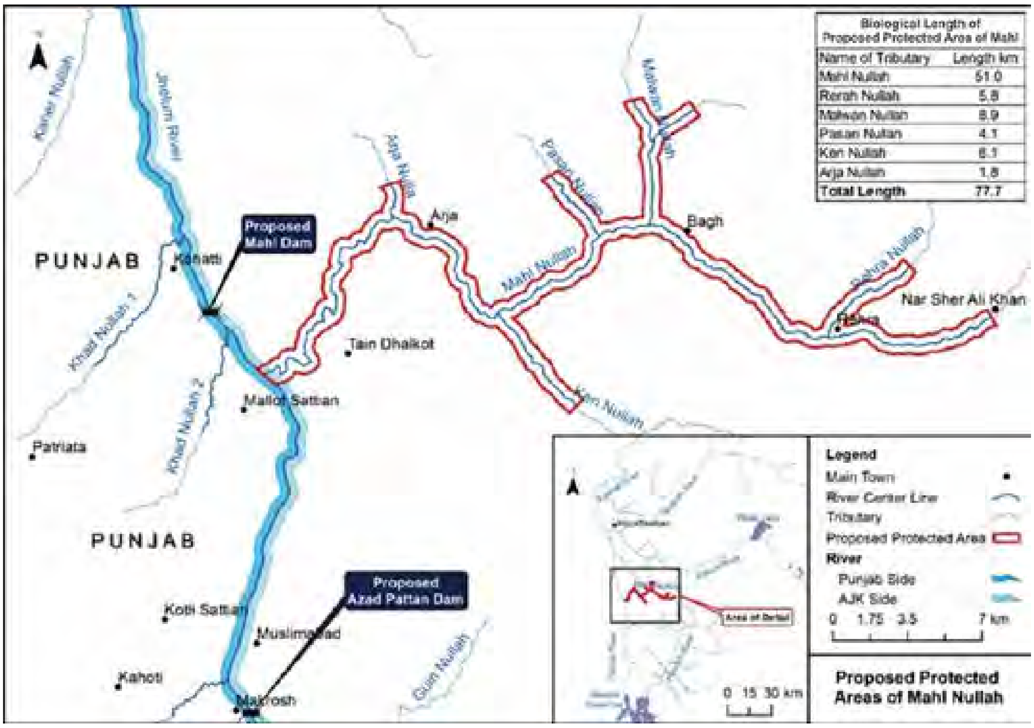
The AJK Fisheries and Wildlife Department is working in the national park to protect the river's ecological resources from anthropogenic disturbances. In addition, Mira Power Ltd. is funding a biodiversity action plan and working with the Himalayan Wildlife Foundation to implement it. This includes putting in place a strong watch-and-ward system to minimize threats, such as illegal and unregulated fishing, to the ecological integrity of the river and supporting the captive breeding of the mahseer. The plan, which is in the early stages of implementation on the Poonch River with promising results, also covers capacity building of the AJK Fisheries and Wildlife Department and awareness raising among the communities (HBP 2015a).

It is recommended that the Poonch River Mahseer National Park continues to be given a high level of protection. If monitoring results show decline in ecological resources, remedial actions should be taken in line with the principles of adaptive management.[27] Additional hydropower projects should only be permitted on the Poonch River if they can bring a net gain of ecological resources above and beyond those from implementing the biodiversity action plan of the Gulpur HPP.

8.3.2 Declaration of New Protected Areas

Modelling studies to assess the cumulative impacts of hydropower projects in the Jhelum River show that most species of conservation importance will almost be wiped out from the main river stem (HBP 2018b). It is therefore imperative to declare additional protected areas to conserve fish habitats and species of concern (**section 3.1.3**) in the basin. The Mahl River, which supports a significant number of fish species including those of conservation importance, has been proposed to be declared a protected area in AJK. The 50 km-long river, located southeast of Bagh and northwest of Rawalakot, is a tributary of the Jhelum River. Its elevation ranges from 500 m to 1,300 m. As a result of this difference in elevation, the water temperature of the river is cooler at its origin (near the town of Nar Sher Khan, 16-17°C in summer) and warmer near its confluence with the Jhelum River (close to 30°C in summer). The Mahl River provides habitats for both cool-water and warmwater fish species as a result of this significant temperature variation along its course. The proposed boundary of the Mahl Protected Area is shown in **Figure 15**.

Figure 15: Proposed Mahl Protected Area



[27] Mira Power Ltd. is supporting a monitoring and evaluation plan to assess the effectiveness of the biodiversity action plan.

Almost 30 fish species have been reported from the Mahl River and near its confluence with the Jhelum River. Common and abundant species reported include the Alwan snow trout (*Schizothorax richadsonii*), Pakistani baril (*Barilius pakistanicus*), Kashmir latia (*Crossocheilus diplochilus*), sucker head (*Garra gotyla gotyla*), flathead catfish (*Glyptothorax pectinopterus*), Bhed catfish (*Glyptothorax stocki*), and Nalbant's loach (*Schistura nalbanti*).

A total of six fish species reported from the Mahl River are of conservation importance. The mahseer, a prized angling fish that is also important for tourism, is listed as Endangered in the IUCN Red List of Threatened Species, while the Alwan snow trout and twin-banded loach are listed as Vulnerable.[28] Both the mahseer and Alwan snow trout are long-distance migratory fish species. Other migratory fish species include the sucker head and Pakistani Labeo. The Nalbant's loach is an endemic fish species restricted to the Jhelum-Poonch Basin.

In addition, the terrestrial habitat in the vicinity of the Mahl River also supports some animals of conservation importance. These include the Oriental white-backed vulture and Egyptian vulture listed as Critically Endangered and Endangered, respectively, in the IUCN Red List. The Himalayan griffon vulture, a migratory bird species, has been reported from the Mahl riverbanks. Two endemic herpetofauna species, rohtas gecko and slender blind snake, have also been reported from the area (HBP 2017c).

The fish species of the Jhelum-Poonch Basin are under threat from several anthropogenic impacts including overfishing, sand and gravel mining from the riverbed and banks, and water pollution. The construction and operation of a cascade of hydropower projects planned on the Jhelum River are likely to exacerbate this loss further since the fish of the tributaries will become isolated from the main river. To prevent the loss of fish species from the Mahl River, anthropogenic activities, such as fishing and sand and gravel mining, need to be regulated and this can only be done by giving the river a legally protected status.

The decline in fish diversity and abundance in the Jhelum River is unavoidable in light of the construction of multiple hydropower projects. Protecting the fish of the Mahl River will help offset those losses because the species distribution of the Mahl River (dubbed a mini-Jhelum) broadly mimics that of the Jhelum (HBP 2017).[29]

The Poonch River Mahseer National Park is the only aquatic national park in the country so far and is managed by AJKFWD with support from the Himalayan Wildlife Foundation. The lessons learned from managing the national park should be incorporated into the management plan of the Mahl Protected Area once it is declared.

While baseline information about aquatic biodiversity is available for most of the Jhelum-Poonch Basin, it should be updated to identify more ecologically important areas, particularly in the tributaries, and declare them protected.

Recommendation 4: Maintain high-level protection to conserve the ecological resources of the Poonch River Mahseer National Park. The Mahl River should be declared a protected area. Other important tributaries should be identified and considered for no or minimal hydropower development, taking into consideration the ecological sensitivity of the river.

8.4
Strengthen Government Departments

More budget and manpower should be allocated for government departments tasked with protecting the river and riparian habitats. Provincial governments should also set aside budget for this purpose, while developers and donors can be approached for additional funds.

Environmental protection agencies and fisheries and wildlife departments require guidance and training on evaluating ESIAs, assessing minimum EFlows for HPPs, providing effective protection, establishing sustainable fishing practices, management of reservoirs and sediment mining, as well as monitoring and evaluation techniques.

IFC has supported several capacity-building initiatives for government departments in recent years. IFC launched the Advancing Sustainable Hydropower Development Webinar series following the completion of a training-needs assessment.

Government ownership and support is vital to ensuring the successful implementation of basin-wide measures, such as a watershed management program (**section 9.5**) and the establishment of an Institute for Research on River Ecology (**section 9.7**).

Recommendation 5: Strengthen government departments to play a more effective role in environmental management and protection by allocating additional budget and manpower as well as enhancing their capacity and capability.

28 The IUCN Red List of Threatened Species. Version 2017-3. http://www.iucnredlist.org/

29 Hagler Bailly Pakistan (HBP). 2017. *Environmental and Social Impact Assessment (ESIA) Report of the 1,124 MW Kohala Hydropower Project*. Report prepared for Kohala Power Company (Pvt.) Limited.

8.5
Maintain Community Uses and Ecosystem Services

Fishing and sand and gravel mining are the two main ecosystem services provided by the river to the local community in the area of management. This section recommends ways to minimize and manage the loss of ecosystem services as a result of developing multiple hydropower projects in the basin.

8.5.1
Sustainable Fishing Program

Many fish that prefer flowing water will be wiped out from the main river following the construction of a HPP. Some fish, however, prefer a lake-like habitat and are likely to survive in reservoirs created by the HPPs. Based on a careful assessment of the relative abundance of these fish species and review of population trends, a sustainable fishing program can be initiated in selected areas, with support from local communities. The focus can be on reservoirs or river sections where fish populations abound. Since the tributaries provide breeding grounds for fish and habitats for the flow-loving fish, it is recommended that fishing in the tributaries be restricted. **Section 8.9** outlines the mitigation measures to manage the reservoirs.

The sustainable fishing program can award angling licenses based on fish population estimates, which should vary for different fish species. The number of licenses for fish of conservation importance, such as the mahseer and Alwan snow trout, should be carefully monitored. Fishing should be permitted only with a line and hook; no cast or gill net should be allowed. Success of the program is dependent on involving local communities in the conservation program; therefore, it is imperative that they are educated and understand the importance of sustainable fishing practices. Purchase of fishing licenses should be open to local communities for subsistence and commercial fishing as well as tourists and visitors who want to engage in recreational fishing.

Initiating a sustainable fishing program will have several benefits:

- Local communities will have the opportunity to eat fish and earn money by selling caught fish in the local market.
- Tourists can enjoy catching and cooking fish by the riverside.
- Licensed fishers will play a role in preventing illegal fishing.
- Revenue will be collected by the Fisheries Department.
- Information about the abundance and diversity of fish catch will be useful for monitoring and evaluation and help determine the number of licenses that should be awarded.

If fish populations are not declining, the sustainable fishing program can be enhanced to include trophy hunting of large-sized fish, such as the mahseer. A revenue-sharing formula can be worked out between the provincial fisheries department and local communities.

In the Poonch River, a community-based program for recreational fishing has been approved by the government and is implemented in collaboration with the Himalayan Wildlife Foundation, which supports the AJK Fisheries and Wildlife Department in protecting the national park. Such initiatives can be replicated in the Neelum River in areas upstream of Dudhnial where the brown trout is found.

Several sustainable fishing programs in Canada, Australia, and the United States and the relevant agencies in these countries can be contacted for guidance and support.

Recommendation 6: Fish surveys for different species should be conducted to monitor the status of fish populations in the river and tributaries. The AJK Fisheries and Wildlife Department should be given the necessary resources and training to perform this role. Based on fish population estimates, a sustainable fishing program can be initiated in selected areas.

8.5.2
Sustainable Sand and Gravel Mining

As outlined in **section 5**, dams form barriers to sediment transportation. As the river slows upon entering the reservoir, sediment settles from suspension. The finer sediments may stay in suspension and pass through the dam outlets during floods, while coarser material is sometimes scoured out through bottom gates to increase storage in a sediment-choked reservoir. Thus, dams can reduce the sediment available to the river downstream, affecting the amount of sand and gravel available for extraction. A balance needs to be struck between meeting community needs for sand and gravel and the integrity of aquatic habitats to avoid excessive damage from uncontrolled mining on the riverbed.

Section 4 shows that mining is fairly widespread in the basin, but its intensity varies. It is not possible to prescribe a uniformed management regime on hydropower projects across the basin because sediment entrapment and release through periodic flushing depends on the specific design of HPPs and sediment inflows. Each project is recommended to develop its own sediment-mining plan. However, developing a basin-wide sediment-mining strategy for all committed HPPs in the Jhelum-Poonch Basin is critical (**section 9.9**). Government departments, particularly provincial EPAs and mining departments, should support hydropower projects to devise such a strategy. Support can be provided by making available existing data and information; assisting with collection of new information; facilitating engagement with stakeholders and other government departments; and providing comments, reviews, and advice.

Recommendation 7: Government departments should support hydropower developers in devising a basin-wide sediment-management strategy that addresses community needs for sand and gravel while protecting the integrity of aquatic habitats.

8.6 Reduce Impacts from Transmission Lines on Terrestrial Ecology

Section 6.3.2 provides an overview of the adverse impacts from building and operating power transmission lines in the area of management. The following mitigation measures are recommended to minimize such impacts on terrestrial ecology:

- Limit the footprint of pylons to a minimum.
- Minimize potential ground disturbance and soil erosion during the construction of pylons.
- Where practical, use existing roads and trails during construction.
- Retain existing low-lying vegetation along the transmission line's right-of-way, thereby minimizing vegetation clearing. This allows for the maintenance of root masses and ground vegetation to reduce the potential for erosion and encourage continued vegetation growth through operations.
- Plant and manage fire-resistant species (for example, hardwoods) within and adjacent to right-of-way in forest areas.
- Allow firefighting access in forest areas.
- Prevent the transfer and spread of alien invasive plant species during routine vegetation maintenance.
- Limit removal or destruction of bird nets during the construction phase.
- Reduce the risk of mortality to birds and bats.
- Maintain 1.5 meters spacing between energized components and grounded hardware or cover energized parts and hardware where spacing is not feasible (IFC 2007).
- Retrofit existing transmission or distribution systems by installing elevated perches, insulating jumper loops, placing obstructive perch deterrents, changing the location of conductors, and using raptor hoods.

The following mitigation measures are proposed for protected and sensitive areas (**section 3.2.2**) in the area of management.

- For protected areas, the relevant IEE or EIA should be completed in accordance with provincial legislation.
- In line with good international practice, new transmission lines should be designed with adequate separations to take into consideration the wingspan and height of birds in areas with known populations of raptors or other birds of concern. In addition to the physical separation of the conductors, the exposed coverings and parts of the structure should also be insulated. It is recommended to maintain a minimum distance of 1.5 meters between the energized parts of the transmission line.
- Install visibility-enhancement objects, such as marker balls, bird deterrents, or diverters on transmission lines in high-use areas (for example, migratory flyways).
- Where possible, avoid construction during the bird-breeding season from March to August.
- Revegetate disturbed areas with native plant species.
- Observe manufacturer machinery and equipment guidelines, procedures with regard to noise, and oil-spill prevention and emergency response.
- Avoid clearing in riparian areas.
- Avoid use of machinery in the vicinity of watercourses.
- Temporarily suspend blasting, drilling, or construction if a large mammal is observed, such as the gray wolf, snow leopard, common leopard, ungulate species, or bears, during construction.
- Reduce risk of mortality to wildlife during construction or maintenance of transmission lines by enforcing speed limits for vehicles. Warning signs should be deployed in areas of high wildlife activity.
- All personnel involved in construction and operation of transmission lines should be provided with environmental-awareness training, including waste disposal, minimizing habitat degradation, preventing spread of alien invasive species, hunting regulations, and what to do if a large mammal is encountered.

Provincial EPAs should develop guidelines for hydropower projects for the laying of transmission lines in sensitive and protected areas. Project owners should observe these guidelines when developing mitigation measures for project-specific environmental management plans.

Recommendation 8: Mitigation measures should be adopted to reduce impacts from the construction and operation of transmission lines. Provincial

EPAs should develop guidelines for the laying of transmission lines, particularly in sensitive and protected areas.

8.7 Guidelines for ESIAs and Biodiversity Action and Management Plans for HPPs

A review of available ESIAs shows that some approved ones were not up to the required standard. These ESIAs did not completely identify the valued environmental and social components (VECs)[30] or predict environmental impacts, therefore, project implementation has led to unmanaged and unmitigated negative impacts.

Recommendations for regulatory reforms to amend the laws governing the ESIAs are outlined in **section 8.2**. It is suggested that zone-specific guidelines for IEE and EIA studies that are not tied to the installed capacities of HPPs should be developed. An outline of these guidelines is available in the *SEA of Hydropower Development in Azad Jammu and Kashmir* (Annandale and HBP 2014).

In addition, every hydropower project is recommended to consider in its ESIA the cumulative impacts of other HPPs in the basin. In this context, the following requirements for considering the cumulative impacts of projects might be incorporated in the terms of reference of full ESIAs (Arikan et al. 2012):

- Define project activities along with other existing, in-progress, or planned projects (for the foreseeable future) in the region that could contribute to cumulative effects on VECs.
- For uncertain cases, scenarios can be developed that include: (i) definite future actions, (ii) definite future actions plus probable future actions (still involving some uncertainty), and (iii) definite future actions plus probable and less probable future actions (with a higher degree of uncertainty).
- Identify the area of influence for the project, which may vary for different types of potential impacts.
- Identify the time boundary for the study, especially with regard to considering actions in the foreseeable future (for example, a concomitant construction period or operation). Scenarios can be developed to identify temporal boundaries as well, particularly when there is uncertainty.
- Identify possible VECs in the region or close to the project's area of influence.
- Identify the VECs in the area of influence that should be considered in the study based on information related to current or anticipated future conditions, the existence of protected species or habitats, and the presence or anticipated presence of other human activities that would adversely affect the VECs.
- Identify project-specific standards, including international relevant regulatory thresholds and standards.

Previously, an ESIA was conducted after the project had been approved by regulatory authorities. However, it is recommended that the ESIA should now be carried out in parallel to the feasibility study of the project. EPAs, PPIB, and PEDO have started requiring the approval of an ESIA by the relevant government agency before giving the green light to a project.

An assessment of transboundary impacts should be included in an ESIA because the development of hydropower projects in India can affect the operation of those in Pakistan.

To conform to international best practices, it is recommended that ESIAs for projects in the area of management follow the guidelines and standards set in IFC Performance Standards and ADB's Safeguard Policy Statement (2009) (see **Annex A**). IFC can assist relevant government departments, particularly provincial EPAs, with capacity building in this regard.

Recommendation 9: Terms of reference for full ESIA studies associated with relevant HPPs should include cumulative assessment requirements and conform to the guidelines of IFC Performance Standards and ADB's Safeguard Policy Statement. The government should adopt international best practice when preparing these guidelines for ESIAs and biodiversity action and management plans for hydropower projects.

8.8 Step Up Protection and Increase Coordination among Government Departments

Although the provincial fisheries and wildlife departments have a clear mandate for protecting ecological resources, unregulated fishing, pollution of waterbodies, and sand and gravel extraction

[30] VECs are environmental and social attributes considered to be important in assessing risks. They include physical features; habitats; wildlife populations (biodiversity); ecosystem services; natural processes (such as microclimate and water and nutrient cycles); social conditions (for example, health and economics); and cultural aspects (such as traditional spiritual ceremonies).

from riverbeds and banks continue unabated. Protection efforts should be strengthened to minimize anthropogenic impacts and imminent threats from hydropower development.

To guarantee success, different government departments, including the fisheries and wildlife departments, forest departments, mining departments, agricultural departments, and environmental protection agencies need to coordinate their conservation efforts. Experience in protecting the Poonch River Mahseer National park shows that support from the Mining Department is crucial to river protection because it issues sediment-mining permits. Unless this is curtailed, the protection efforts of the Wildlife and Fisheries Department cannot succeed.

Recommendation 10: Step up efforts to protect aquatic ecological resources from anthropogenic impacts, such as illegal fishing, sediment extraction, and pollution, and increase coordination among relevant government departments.

8.9 Recommendations for Management of Reservoirs

Although almost all hydropower projects in the Jhelum-Poonch Basin are the "run-of-river" type without large storage capacities, reservoirs of different lengths will be created by the HPPs upstream of the dam or weir. These reservoirs can be managed to develop fish hatcheries for commercial fish. **Section 7.4.2** outlines the issues and recommendations for managing the reservoirs.

Recommendation 11: Guidelines for reservoir management should be formulated. Selective commercial and recreational fish harvesting may be permitted, but the reservoirs should not be stocked with exotic fish species. In addition, managers and local fishers should be trained to monitor the reservoirs for invasive fish species. The reservoirs should be managed to protect migratory birds and develop recreational activities for local communities where appropriate.

8.10 Consistency in Application of International Best Practices

Environmental regulators often review ESIAs submitted by the private sector differently from those submitted by government-owned projects. **Section 7.5.1** outlines the issues and problems associated with this practice.

Recommendations to address this issue include the following:

- EPAs should be more proactive in maintaining consistent standards for environmental assessment and performance irrespective of project ownership.
- EPAs should require hydropower developers to follow international good practice guidelines, such as IFC's handbooks for environmental flows and cumulative impact assessments (CIAs).
- EPAs can hold periodic review sessions with senior management of hydropower projects to bring them up-to-date on best practices in environmental management, mitigation, and monitoring.
- EPAs can conduct a periodic basin-wide review of the environmental performance of hydropower projects so that all HPPs are adhering to the same operating standards to reduce their negative impacts.

Recommendation 12: Environmental regulators, particularly the EPAs, should be consistent in evaluating the environmental assessment and performance of hydropower projects irrespective of ownership. They should also encourage developers to follow international good practices for environmental management, mitigation, and monitoring.

8.11 Including Environmental Costs in Project Tariffs

As outlined in **section 7.2.2**, inclusion of environmental costs in the electricity tariff has not been a standard practice or clearly mandated for Central Power Purchasing Agency, the government-owned power market operator, or the National Electric Power Regulatory Authority (NEPRA). NEPRA has played a responsible role over the past five years and considered requests for including environmental costs associated with project development in the tariff, but more needs to be done to clearly establish the practice.

Recommendation 13: A methodology should be developed by NEPRA for calculating the cost of mitigating the negative environmental impacts of a hydropower project and incorporating it into the electricity tariff. In addition, capacity building of NEPRA staff should be carried out to address emerging concerns in the environmental design of hydropower projects, such as avoidance of peaking and operation of projects at baseload in sensitive river environments. Information on the importance of environmental costs and their inclusion in tariffs should be shared and discussed with relevant government departments and agencies.

8.12
Prepare a Strategic Environmental Assessment for Hydropower Development in the Basin

As outlined in **section 7.1**, IUCN supported the development of the *SEA of Hydropower Development in Azad Jammu and Kashmir* (Annandale and HBP 2014). This SEA should be updated using the data collected during the ESIAs and monitoring of hydropower projects as well as lessons learned from project development. The scope of the SEA should be expanded to include KP and focus more on subbasins such as Kunhar where more developments are planned. The sustainable hydropower development strategy outlined in this document can provide guidance on how to revise the SEA. Government planning departments, such as PEDO and AJK Power Development Organization, can be tasked with this exercise.

Recommendation 14: The SEA prepared by IUCN (Annandale and HBP 2014) should be revised and updated by the government planning departments to incorporate new available information and include the Kunhar Basin.

9. RECOMMENDATIONS FOR HYDROPOWER DEVELOPERS

This section provides recommendations for hydropower project developers to minimize negative environmental and social impacts from the construction and operation of multiple hydropower projects in the basin. Most of these recommendations include basin-wide measures and require close coordination not only among all hydropower projects in the basin but also support from relevant government departments.

The recommendations outlined in this section are listed in order of importance based on the prioritization survey of participants at a stakeholder meeting organized by IFC in January 2019 (**section 1.6**). Additional recommendations from **section 7** are also summarized at the end of the section.

9.1 Design HPPs to Balance Power Generation and Environmental Impacts

Large hydropower projects designed to harness all of the river's energy to generate electricity can maximize power generation and financial benefits, but they also bring significant negative environmental and social impacts. This is because dams modify the river's flow regime—the fundamental driving force of the river ecosystem—leading to knock-on effects on the river's sediment, chemical, and thermal regimes, its biota, and all the ecosystem services valued by people. The more the natural flow regime is changed, the greater the implications will be for the ecosystem and people. Dams are thus a mixed blessing: they ensure water supply for irrigation and hydroelectric power but can also cause declining fisheries and water quality, failing estuaries, and the loss of highly productive floodplains.

Hydropower project proponents should weigh the benefits of power generation while considering the loss of ecological resources, ecosystems and related services, and livelihoods. One way to tackle this is by using holistic methods to calculate the minimum environmental flow. It is also important to include environmental considerations at each project-development stage, including design, construction, and operation.

Recommendation 1: Hydropower projects should be designed to balance power-generation benefits and environmental and social impacts by including assessment of environmental and social risks at the feasibility stage.

9.2 Prepare and Implement a Biodiversity Action or Management Plan

A biodiversity action plan (BAP) or biodiversity management plan (BMP) is an internationally recognized system designed to address threatened species and habitats as well as protect and restore biological systems. While an EIA helps hydropower project proponents meet regulatory requirements and minimize the impact of their operations on the environment, a BAP focuses on the conservation, protection, and enhancement of biological resources in the selected area. Where biodiversity values of conservation importance are associated with a project site or its area of influence, a BAP or BMP is a useful means to focus a project's mitigation and management strategy (IFC 2012).

Several hydropower projects in the area of management, particularly those financed by IFC, have committed to implementing a BAP or BMP in a selected area of river upstream and downstream of the dam. These include the Gulpur HPP on the Poonch River, the Balakot HPP on the Kunhar River, and the Azad Pattan HPP, Karot HPP, Kohala HPP, and Mahl HPP on the Jhelum River. The objective is to establish a system to protect the riverine ecosystem, particularly the fish species of concern, from anthropogenic impacts, such as illegal fishing and sediment extraction from riverbed and banks.

While several private hydropower projects have developed a BAP or BMP, it is important for government-sponsored hydropower projects to do the same.

Recommendation 2: Both public- and private-owned hydropower projects should develop and implement a BAP or BMP in line with international best practices.

9.3
Prepare and Implement a Stakeholder Engagement Plan and Grievance Redress Mechanism

A stakeholder of a hydropower project is defined as someone who is interested or involved in or affected by the project and its associated activities. Project stakeholders can comprise a broad range of groups, such as affected communities, government agencies, partners, contractors, suppliers, financiers, catchment residents, the media, academics and experts, civil society, and NGOs (IHA 2018).

It is important to identify all stakeholders in meaningful groups—known as stakeholder mapping—as a first step of engagement. Once stakeholder groups are identified, progressive levels of communications and consultation planning and analyses can be undertaken, keeping in view each group's importance, influence, and the extent to which each will be affected by a hydropower project. Stakeholder engagement should continue throughout the project duration.

Project owners need to develop a technically sound and culturally appropriate stakeholder engagement plan for all involved parties from an early stage of development. The plan should provide adequate and timely information to stakeholders and establish grievance mechanisms to address their concerns and legitimate complaints. Such mechanisms should include procedures to track and respond to any grievances; steps on how issues will be escalated if they cannot be quickly resolved; commitments to inform stakeholders of status or outcomes; and avenues of legal recourse. Grievance mechanisms should be formally developed, easily accessible, and well understood by relevant parties, particularly those who intend to use them (IHA 2018). This will prevent issues and complaints from getting out of hand once the project begins construction.

Recommendation 3: Hydropower project developers should develop a stakeholder engagement plan and a grievance redress mechanism in line with international good practices.

9.4
Set Up a Database for the Jhelum-Poonch Basin

A database should be set up to store and provide up-to-date information on hydrology, ecology, geomorphology, water quality, climate, socio-economics, and hydropower projects in the Jhelum-Poonch Basin. A complete list of indicators proposed for each parameter is provided in **Annex H**.

The key objective of the database is to provide a unified platform for relevant stakeholders to store and access data collected by themselves and others as well as to facilitate the calculation of indicators of change. For developers in the Jhelum-Poonch Basin, the database will assist with data collection and analysis for monitoring and evaluation as required by the biodiversity action or management plans of their projects.

The database can be housed and maintained by the proposed Institute for Research on River Ecology (IRRE) (**section 9.7**). Researchers can use the data to access long-term trends in degradation or recovery in the river ecosystems and study linkages between various aspects and parameters defining the ecosystems.

Experts associated with the institute, hydropower developers, and monitoring and evaluation consultants will be responsible for inputting the collected data. Data updates will be performed according to the frequency requirements specified for the database. System users will be given customized, password-controlled access to the database, which will allow them to use it in accordance with their respective roles.

A framework for the Jhelum-Poonch database has been developed as part of this assignment and is provided in **Annex H**.

Recommendation 4: Set up a database for the Jhelum-Poonch Basin to allow storage and access of data on hydrology, ecology, geomorphology, water quality, climate, socio-economics, and hydropower projects.

9.5
Establish a Watershed Management Program

A watershed management program has been proposed for the Jhelum River Basin to focus on improving water quality, which is critical for biodiversity protection in the long run (HBP 2017b). Individual project owners will make financial contributions to the program that considers the size of the project and its impact on aquatic biodiversity. The program will be established subject to approval of associated costs in the tariff by NEPRA. Additional support and resources can be mobilized from participating government departments including forests, wildlife, fisheries, agriculture, and irrigation. It is recommended to route corporate social responsibility investments through the program to maximize the benefit from investments for both the industry and the communities.

The program will manage land use, water use in both agriculture and households, water quality, and reforestation to meet community needs for fuel wood and timber while adhering to the limits of sustainable harvesting to reduce erosion and landslide risks. In case corporate social responsibility investments are included, they can be made in areas such as clean drinking water, health, livestock, and improvements in agricultural productivity. The funds can also be allocated to education, arts, handicrafts (such as carpet weaving, embroidery, and fabric stitching), and sustainable tourism.

The establishment of a watershed management program will ensure a coordinated approach by all HPPs in the basin and reduce the cost for individual HPP to implement the program.

Recommendation 5: Hydropower projects should contribute toward the establishment of a watershed management program to reduce erosion in the catchments and flow of pollutants into the river.

9.6 Maximize Synergistic Project Development

Where more than one project is built in close proximity on the same tributary or river section, developers should coordinate with each other and redesign projects based on a synergistic approach. This can maximize positive impacts and mitigate adverse environmental impacts. For example, if three projects are being planned on the same tributary, the highest one can design a storage wall to regulate flow for all three, thereby preventing the need for each downstream project to individually store water. It may also help ensure environmental flows downstream during the dry season (Annandale and HBP 2014).

Another example is the construction of transmission lines. A remote site may require significant investment in transmission infrastructure to connect the project to the local grid. With strategic planning, however, this cost can be shared if several run-of-river projects are developed in close proximity. Similar efficiencies could be achieved for access points, construction sites, labor camps, and storage areas.

Coordinated measures can be integrated into the design and operation plans to mitigate cumulative impacts at the watershed level. These measures include maintaining adequate downstream flow regimes; coordinating the design of fish ladders; contributing to native fish hatcheries, fish restocking, and aquaculture activities; and designing fish-diversion structures at intakes to avoid entrapment.

Recommendation 6: If HPPs are close to each other on a main river or tributary nullahs, proponents should consult each other about project design to enable synergistic development. Such consultation should be mandatory even if project initiation schedules are not synchronized.

9.7 Establish an Institute for Research on River Ecology

An Institute for Research on River Ecology (IRRE) has been recommended in the biodiversity management plan of the Karot HPP. The same approach has been incorporated into the biodiversity action plans of the Azad Pattan, Kohala, and Mahl HPPs.

The proposal is for all hydropower project developers to contribute toward the establishment and operation of the IRRE as a basin-wide institution and jointly benefit from its research outputs. Each project's contribution will depend on its size and impact on aquatic biodiversity. The establishment of the IRRE is dependent on NEPRA's approval of the associated costs in the electricity tariff.

The IRRE will perform research and development on the following: captive breeding and stocking of fish of conservation importance that are affected by projects; fish passages suited to local species; river conditions; dam designs; genetic studies to determine the risk of in-breeding and ways to lower such risks; assessment of impacts on river biodiversity; and use of EFlow models (such as DRIFT) to assess the cumulative impacts of projects.

The proposed institute will help project owners build ecological databases and research and analysis capabilities, which can help lower their individual project's environmental management costs. The provincial fisheries and wildlife departments in the area of management will work closely with the project developers and supervise the establishment of the IRRE.

Recommendation 7: Hydropower projects should contribute toward the setting up of an Institute for Research on River Ecology to conduct research on river biodiversity, impacts of HPPs, and mitigation options.

9.8 Increase Environmental-Management Capacity

Developers should strengthen their environmental-management capability so that they can better incorporate environmental considerations into the design, construction, and operation of hydropower projects. It will be beneficial to gain a better understanding of the ecological resources in their respective project area, the importance of designing projects to balance power generation and environmental impacts, methodologies for EFlow assessments, setting up detailed hydrology and sediment-transport models, and preparation and implementation of sediment-management methods.

Recommendation 8: HPP staff and consultants should enhance their environmental management and protection capabilities by staying abreast of latest studies and research as well as participating in training and capacity-building initiatives.

9.9 Develop a Sediment-Management Strategy

Currently available information clearly indicates that the rivers' sediment regime will be highly altered by hydropower development. It is necessary to develop a sound sediment-management strategy to minimize and mitigate these impacts, including the following components:

- Improve understanding of sediment-transport processes in the basin. This study's sediment analysis (**section 5**) was based on EIAs that were decades old with limited measurements. Coordinated sediment transport and geomorphic monitoring throughout the basin is required to provide a more up-to-date and accurate picture of the current situation. Monitoring sediment transport upstream and downstream of existing HPPs can also verify some assumptions about trapping efficiency and channel changes as a result of multiple HPPs on the same river. This information should be used as a baseline against which future changes can be assessed and contribute toward a long-term strategy.
- Areas of high ecological concern, such as spawning grounds or exposed cobble bars, should be surveyed and the grain-size characteristics of the substrate should be quantified. The maintenance of these areas should be used as management targets for the sediment management plan.
- A basin-wide, long-term sediment management strategy should be devised based on the HPP locations, the timing of implementation of each project, the potential for each project to discharge sand annually, and the time required for coarse sands and gravels to be discharged from the impoundment. Based on these factors, sediment-routing and sediment-flushing regimes can be coordinated to ensure the continued delivery of sand and coarser material to river reaches of high ecological importance. IFC is facilitating the creation of a Hydropower Developers Working Group, which will allow the various HPPs in the Jhelum Basin to coordinate with each other and discuss concerns and issues. The working group, once established, can coordinate the development of a sediment-management strategy for the basin.
- Sediment flushing should be coordinated between projects with the aim of enhancing sediment transport downstream but also avoiding harm from flooding or choking of the riverbed and banks because of the deposition of large volumes of fine-grained sediment associated with flushing in the dry season.
- Flushing guidelines can be considered to provide guidance on the seasonal timing of flushing, flow rates, suspended sediment concentrations, flushing durations, and monitoring. Developers should also be required to notify downstream HPPs and communities.
- Individual hydropower projects can develop their own sediment-mining plans in line with the basin-wide sediment strategy outlined above.
- Recommendations for sustainable sediment mining from areas upstream of the dam should be established in consultation with the government mining department, environmental protection agencies, and fisheries and wildlife departments.

Recommendation 9: A basin-wide sediment-management strategy should be developed for all committed hydropower projects in the Jhelum-Poonch Basin.

9.10 Participate in the Hydropower Developers Working Group

The Hydropower Developers Working Group, an IFC initiative, aims to provide a platform for project owners to collaborate on the sustainable management of the Jhelum-Poonch Basin. Developers can share lessons learned, discuss issues of mutual concerns, and develop strategies to effectively manage them. Areas where developers can cooperate include the setting up of a watershed management program (**section 9.5**), synergistic project development and operation (**section 9.6**), establishing the IRRE (**section 9.7**), and coordinated sediment flushing from the dam (**section 9.9**).

Recommendation 10: Hydropower developers should collaborate on issues of mutual concern through the Hydropower Developers Working Group (HDWG) and share lessons learned and good industry practices.

9.11 Mitigate Construction Impacts

Section 7.3 summarizes negative impacts from the construction of hydropower projects, which are outlined below for ease of reference:

- During construction, fish are able to move downstream through the diversion tunnels but not upstream. This can result in a congregation of fish at the bottom of the tunnels where they are easily poached and also an accumulation of fish populations downstream that cannot move upstream.

- An impoundment or commissioning of the reservoir often requires stoppage or high reduction of flow downstream, which causes negative impacts on fish and other aquatic organisms downstream.
- Although ESIAs usually prohibit the collection of sand and gravel from the riverbed for construction as well as the dumping of sediments into the river, these are common practices in the basin.

Measures that can be taken to address these impacts include:

- HPPs should develop techniques to prevent migratory fish from going downstream through diversion tunnels, or construct the tunnels in such a manner that fish can swim back upstream. Research on such techniques is needed.
- HPPs should develop an impoundment or commissioning plan that considers impacts on downstream aquatic ecosystems and people. EPAs should require this plan as part of an ESIA.
- Third-party inspectors should be hired by the EPAs and lenders to ensure that HPP construction materials are not taken from the riverbed and sediments are not dumped into the river.

Recommendation 11: Mitigate construction impacts by transporting fish from downstream to upstream of the dam, developing an impoundment or a commissioning plan, and banning sediment extraction and dumping into the river.

9.12
Address Operations Impacts

Section 7.4 summarizes the negative impacts from operation of hydropower projects. These may include emergency shutdown of turbines or powerhouse and subsequent stoppage or reduction in flow to the downstream river reaches with negative impacts on people and aquatic ecosystems downstream.

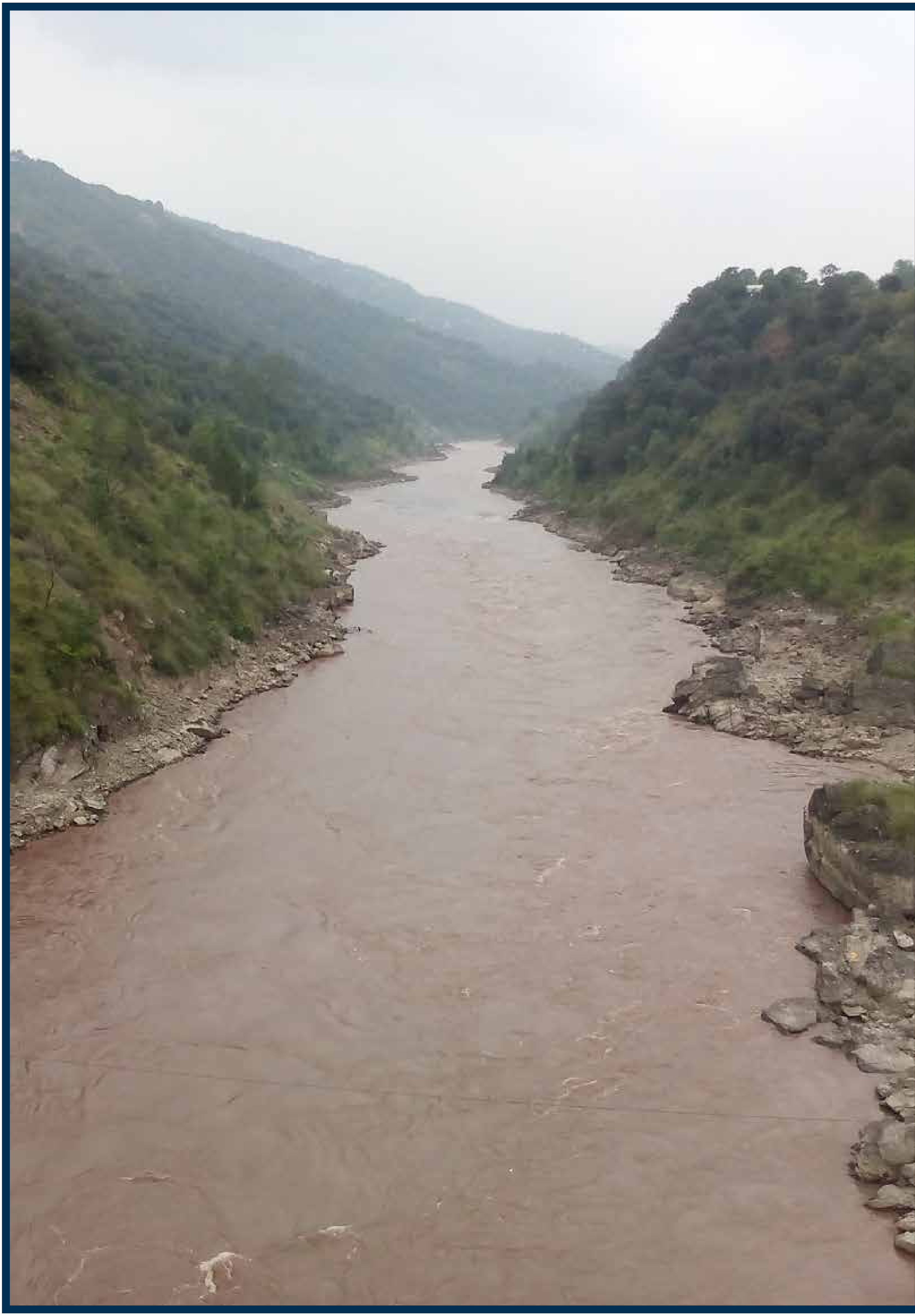
Recommendation 12: Developers should devise a standard operating procedure to address cases of accidental or emergency stoppage of water flow during operation.

9.13
Develop a Monitoring and Evaluation Plan and Implement Adaptative Measures

The objective of monitoring is to evaluate changes, particularly biodiversity indicators, as a result of the operation of a hydropower project and implementation of protection measures as part of a biodiversity action or management plan.

To enable standardized, repeatable collection of data and analysis, each hydropower project should develop a monitoring and evaluation plan outlining the methodology, indicators, locations and timings of monitoring. If monitoring data indicates the project is having a negative impact on the ecology and ecosystem services, the developer may be required to modify the project’s environmental management and monitoring plans as well as make operational changes in the commercial agreements.

Recommendation 13: Develop and implement a monitoring and evaluation plan as well as adaptive measures if monitoring results indicate significant negative impacts from HPPs on ecology and ecosystem services.



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Annex A

Regulatory and Institutional Framework

Protecting the environment and the ecosystem services provided by the river is central to ensuring sustainable hydropower development. This section summarizes the policies, laws and regulations as well as the institutional framework relevant to both hydropower development as well as environmental conservation.

A.1
Policies, Laws and Plans for Power Sector

A number of national and provincial policies and legislations govern the development and distribution of hydropower development in the Area of Management (AoM). Since the AoM straddles the two provinces of Pakistan (Punjab and Khyber Pakhtunkhwa) as well as the state of Azad Jammu and Kashmir (AJK), this section provides a brief description of the national and provincial power related policies, laws and regulations in these three territories.

A.1.1
National Regulations

National Power Policy 2015

The Government of Pakistan (GoP) announced a power policy in 2015 offering enhanced incentives and simplified processing to bridge the demand-supply gap in the minimum time through generation of affordable electricity for socio-economic uplift of the country. The Policy offers profitable business opportunity and the GoP urges the local and international investors to participate in the development of power projects.

The main objectives of the Power Policy 2015 are:

- To provide sufficient power generation capacity at the least cost
- To encourage and ensure exploitation of indigenous resources
- To ensure that all stakeholders are looked after in the process; a win-win situation
- To be attuned to safeguarding the environment

The following types of hydropower projects are covered under this Policy:

- Raw Site hydropower projects (i.e., for which no feasibility study and detailed engineering design yet has been carried out) to be developed in the private sector;
- Hydropower projects having already completed feasibility study in either private or public sector, to be further developed in the private sector;
- Hydropower projects under Public Private Partnership arrangement;
- Private, Public or Public-Private Partnership Hydropower Projects initiated/awarded by Governments of the Provinces, AJK or Gilgit-Baltistan where Power Purchaser is a Federal Entity, Transmission and Distribution Network of a Federal Entity is used, tariff is determined or approved by National Electric Power Regulatory Authority (NEPRA) and GOP Guarantor is required.
- Project undertaken by provinces, AJK or Gilgit-Baltistan (GB) where they are dealt by Provincial Regulator or Power Purchaser is a provincial entity and GoP guarantee is required, on request of the relevant Government, such Projects may be further handled by Private Power and Infrastructure Board (PPIB) and respective Provincial Entity under Tri-partite Letter of Support regime.

Only run-of-river hydropower projects i.e., where irrigation, flood control and seasonal storage are not involved will be offered under this policy unless otherwise specifically permitted by the GoP in consultation with the concerned province. The run-of-river projects may have some ponding facility for absorption of daily flow fluctuation and for daily peaking operation of the power plant. The project should be designed and implemented with a view of optimum utilization of potential of the site.

Alternative and Renewable Energy Policy 2019

An Alternative and Renewable Energy Policy was approved by the Government of Pakistan in 2019 with a vision for development of an efficient, sustainable, secure, affordable, competitive and environment friendly power system while promoting indigenization of energy resources and development of local manufacturing capabilities in such technologies.[1] Hydropower development is not covered by the Policy.

WAPDA's Vision 2025 Hydropower Development Plan

In 2008, Pakistan's Water and Power Development Authority (WAPDA) announced its Vision 2025-National Water Resource and Hydropower Development Program designed to organize and

[1] Government of Pakistan (GOP). 2019. Alternative and Renewable Energy Policy. Available at Alternative Energy Development Board https://www.aedb.org/images/ARE_Policy_2019_-_Gazette_Notified.pdf

prioritize the development of hydropower projects in the short, medium and long term to meet the power deficits facing the country.[2] Vision 2025 details all of the hydropower development related activities in Pakistan and AJK being undertaken along with their status and progress. Identified projects are designated, either to the public or private sector, or to a public-private partnership for construction and commissioning depending upon the urgency to complete a project while keeping in view the resources available from the government or private funders.[3]

A.1.2 Provincial Regulations

Azad Jammu and Kashmir (AJK)

Hydropower development in the state of AJK is governed chiefly by the Government of Pakistan's Power Generation Policy 2015[4], formulated by Pakistan's Ministry of Water and Power.

The outline of the policy to promote the development of hydropower projects in AJK covers the following aspects.

- Award of raw sites on first come first served basis to interested investors who establish their financial soundness to meet the equity component of investment.
- Award of solicited sites on the basis of competitive bidding to investors/interested investors on reimbursement of feasibility study costs.
- Leasing of state-owned land on concessional rates required for project development to Investors/ developers without provision for escalation of lease rates.
- Support in acquisition/leasing/purchase of private owned land through revenue department.
- Support in setting up regional receipt/dispatch grids for optimal utilization of capacity.
- Generous package for BOT (Build, Operate, Transfer) implementation including 5 years grace period for extension of operation.
- Generous tax/levies incentives to promote cottage industrial/agricultural units running on hydropower projects on the concept of captive generation.

The Government of AJK shall extend all possible support & assistance to the prospective potential investors/project developers, who face difficulties in framing their proposals or obtaining necessary consents from the departments concerned.

Punjab

The Punjab Power Policy 2006 (revised in 2009) provides policy framework to the development of power generation in both public and private sectors and has made possible formation of governmental technical departments and renewables specialized companies to foster and execute power projects in public, private and public-private partnership modes with indigenous power resources. The main objectives of this Policy are to:

- provide adequate power generation capacity at the least cost.
- encourage and ensure exploitation of indigenous fuel (oil/gas/coal/biomass) and hydel resources.
- encourage utilization of wind and solar energy for power generation.
- promote indigenization.
- encourage the local engineering industry to form joint ventures with foreign companies for participation in the development of power generation projects
- protect the environment.

Khyber Pakhtunkhwa (KP)

The Government of Khyber Pakhtunkhwa (GoKP) has announced a new Hydropower Policy 2016 which offers enhanced incentives and simplified processing mechanism for setting up of power generation plants to bridge the demand supply gap in the minimum time through generation of affordable electricity. To achieve these purposes, the GoKP has designated Pakhtunkhwa Energy Development Organization (PEDO) as the one window facilitator and implementation agency of this policy. The KP Hydro Power Policy 2016 offers profitable business opportunity, modern engineering and technical processes, lower costs of doing business so that local and international investors may fully participate as partners in the development of hydro power projects.

The main objectives of the Policy are to:

- provide sufficient capacity for power generation at least cost

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[2] Siddiqui, R. H. (2008, September 24). Wapda 'Vision 2025' to help solve power crisis. Retrieved May 24, 2013, from The Nation: https://nation.com.pk/24-Sep-2008/wapda-vision-2025-to-help-solve-power-crisis

[3] Pakistan Water and Power Development Authority. (2011). Annual Report 2010 - 2011. WAPDA House, Lahore - Pakistan: Public Relations Division (WAPDA).

[4] Policy available at official website of Private Power Infrastructure Board. https://www.ppib.gov.pk/policies/Power%20Generation%20Policy%20 2015%20small.pdf

- encourage and ensure exploitation of indigenous resources including renewable energy resources, human resources, participation of local engineering and manufacturing capabilities
- ensure all stakeholders are looked after in the process
- be attuned to safeguarding the environment
- encourage private sector to develop hydel potential and utilize the power generation for the industry as well as for other purposes in accordance with Interim Power Procurement Regulation (2005)

A.2
Institutional Framework for Power Sector

A.2.1
Structure of Power Sector at National Level

The power sector in Pakistan consists primarily of two systems: corporatized generation, transmission and distribution companies that have been formed out of the former vertically-integrated monolithic power utility, the Water and Power Development Authority (WAPDA)[5,6], and the vertically-integrated K-Electric (KE), formerly Karachi Electric Supply Company (KESC).

Ministry of Energy

The Ministry of Energy is a Pakistan Government's federal and executive level ministry created on 4 August, 2017 after merging of the Ministry of Petroleum and Natural Resources with the power division of the Ministry of Water and Power (now renamed Ministry of Water Resources), respectively. The Ministry has two divisions – petroleum and power. The Ministry of Energy provides the policy framework and administrative oversight for the operation of the power sector, excluding the nuclear based power plants which are under the administrative control of the Ministry of Defense and operated by the Pakistan Atomic Energy Commission (PAEC).

WAPDA

WAPDA, an autonomous body and a federal institution, came into existence by virtue of an Act of Parliament in 1958 for the purpose of coordinating and providing a unified direction to water and power development schemes in all territories under Pakistan's control including AJK.

In 1998, WAPDA's Power Wing was restructured into 13 independently functioning corporate entities with an aim to gradually move the power market towards competition, inject private capital in mainstream development, and improve the sector's operational efficiency. Under the restructuring process, the functions of generation, transmission and distribution were separated through the creation of 13 distinct entities – 4 thermal generation companies (GENCOs), one central National Transmission and Dispatch Company (NTDC), and 11 distribution companies (DISCOs) – through an extensive corporatization process in which the assets and liabilities of these companies were identified and separated, and independent boards of directors appointed to manage the affairs of each new company. These DISCOs cover the areas of Faisalabad, Gujranwala, Hyderabad, Sukkur, Islamabad, Karachi, Lahore, Multan, Peshawar, Quetta and tribal areas.

In 2004 WAPDA's power mandate was transferred to Pakistan Electric Power Company (PEPCO) which was established in October 2007. WAPDA is now fully responsible for the development of hydel power and water sector development projects and the maintenance and running of power houses. PEPCO, with an independent Chairman and Managing Director, is now vested with the responsibility of thermal power generation, transmission, distribution and billing.

K-Electric (KE)

K-Electric (then KESC) was incorporated in 1913 and is responsible for the generation, transmission of electricity in Karachi (in the province of Sindh) and its adjoining areas. It is not relevant to the Area of Management.

PPIB

Private Power and Infrastructure Board (PPIB)[7 8] is a board, which was established under Pakistan's Ministry of Water & Power (MW&P) in 1994. It is chaired by the Minister for Water & Power and includes representatives from each of the four provinces of Pakistan as well as AJK. It was set up to provide a 'one-window' support to Independent Power Producers (IPP).

[5] Pakistan Water and Power Development Authority. (2011). Annual Report 2010 - 2011. WAPDA House, Lahore - Pakistan: Public Relations Division (WAPDA).

[6] Pakistan Water and Power Development Authority. (2012). Hydro Potential in Pakistan. WAPDA House, Lahore - Pakistan: Public Relations Division (WAPDA).

[7] Private Power and Infrastructure Board. (n.d.). Hydel Potential in Pakistan. Islamabad: PPIB, Ministry of Water and Power.

[8] Private Power and Infrastructure Board. (n.d.). Private Power and Infrastructure Board. Retrieved May 16, 2013, from http://www.ppib.gov.pk/

PPIB facilitates investors in establishing private power projects and related infrastructure; executes Implementation Agreements (IA) with project sponsors and issues sovereign guarantees on behalf of Government of Pakistan (GoP). With regards to hydropower development in AJK and the provinces of Pakistan it coordinates with the provincial governments, local governments, AJK and regulatory bodies in implementation of the power policies, if called upon to do so. It also coordinates and facilitates sponsors interested in developing hydropower projects in obtaining consents and licenses from various agencies of the federal government, provincial governments, local governments and AJK. It also acts as an agent for the development, facilitation and implementation of power policies and related infrastructure in Gilgit-Baltistan and AJK.

Alternative Energy Development Board

The Government of Pakistan established the Alternative Energy Development Board (AEDB) in 2003 to create a conducive environment in the country for private investments in renewable energy. It has been designated as a 'one-window' facilitator at the federal level for processing Renewable Energy (RE) projects of all sizes. The AEDB can issue a Letter of Intent , which is the first contract that a developer enters with the AEDB. The AEDB also has developed the standard power purchase agreement (known as the Energy Purchase Agreement (EPA)) and the government support agreement (the Implementation Agreement (IA)).

Pakistan Council of Renewable Energy Technologies (PCRET)

Together with AEDB, Pakistan Council of Renewable Energy Technologies (PCRET) also supports country's RE development by coordinating Research and Development and promotional activities in different RE technologies. It was established by merging the organizations under the Ministry of Science and Technology, namely, National Institute of Silicon Technology (NIST) and the Pakistan Council for Appropriate Technologies (PCAT) on May 8, 2001.

National Electric Power Regulatory Authority (NEPRA)

The National Electric Power Regulatory Authority (NEPRA) was established under the *Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997*. It issues operating licenses and approves tariffs and contracts at all levels of market operations and for consumers of electricity. Nuclear power plants are partially regulated (for operational and safety purposes) by the Pakistan Nuclear Regulatory Authority (PNRA), while their tariff setting function remains with NEPRA.

NEPRA regulates the power sector in Pakistan and protects the interests of consumers and companies providing electric power services. As such, apart from monitoring the performance of transmission and distribution licensees, NEPRA also monitors the performance of generation licensees.[9]

National Transmission and Despatch Company (NTDC)

National Transmission & Despatch Company (NTDC) commenced commercial operation in December 1998. NTDC provides Pakistan with reliable, efficient, and stable transmission network and Despatch Services through the adoption of sustainable best international practices that ensure optimum utilization of resources to meet the transmission services requirements of generators and end users and maximize return to stakeholders. NTDC links Power Generation Units with Load Centers spread all over the country and thus establishes and governs one of the largest interconnected Networks. NTDC is responsible for evacuation of Power from the Hydroelectric Power Plants (mainly in the North), the Thermal Units of Public (GENCOs) and Private Sectors (IPPs) (mainly in the South) to the Power Distribution Companies (DISCOs) through primary Extra High Voltage (EHV) Network.[10]

Central Power Purchasing Authority (CPPA-G)

Central Power Purchasing Agency (CPPA-G) is a Company incorporated under the Companies Ordinance, 1984 and wholly owned by the Government of Pakistan (the "GOP"). Since June 2015, CPPA-G has assumed the business of National Transmission and Despatch Company (the "NTDC") pertaining to the market operations and presently functioning as the Market Operator in accordance with Rule-5 of the NEPRA Market Operator (Registration, Standards and Procedure) Rules, 2015 (the "Market Rules").

The Company is currently performing eight major functions segregated into six core and two support functions. The core functions include (i) settlement, (ii) power procurement on behalf of DISCOs, (iii) finance, (iv) legal and corporate affairs, (v) strategy and market development, (vi) monitoring and

[9] Official website of National Electric Power Regulatory Authority (NEPRA). Available at https://nepra.org.pk/About.php

[10] Official Website of National Transmission and Despatch Company (NTDC). Available at: http://ntdc.gov.pk/

coordination. The support functions include (vii) human resource management and (viii) information technology.[11]

A.2.2 Structure of Power Sector in State and Provinces

Azad Jammu and Kashmir (AJK)

Electricity Department

Electricity Department of Azad Jammu and Kashmir was developed to promote electricity and to improve financial effectiveness of the state. The Department is responsible for assisting the state in implementation of overall government policies related to power/ electricity. The major functions of the Department are to ensure transparency of regulatory framework, accommodate, promote and facilitate the people of the state of Azad Jammu and Kashmir in matters related to electricity.[12]

Power Development Organization

The Government of AJ&K established Power Development Organization (previously Hydro Electric Board) in 1989, to plan and to undertake development of identified hydro potential. The Power Development Organization (PDO) is responsible for developing hydropower potential of the state and doing so by especially encouraging private sector involvement. The PDO also extends support in project implementation by identifying and ranking potential hydropower sites in AJK, preparing Feasibility Study Reports for approved projects, as well as site construction management and commissioning of projects and operation, maintenance and revenue collection for commissioned power stations.

Private Power Cell (PPC)

The AJK Private Power Cell (PPC) was established in 1996 to facilitate private sector participation for hydropower generation in AJK. It has been established under the then Hydroelectric Board (HEB) to provide a 'one-window' support to private sector investors in matters concerning development of hydropower projects and related infrastructure. These matters include negotiating the Implementation Agreement (IA) with a private sponsor executing a hydropower project less than 50 MW in capacity in AJK.

Punjab

Punjab Energy Department (PED)

Punjab Energy Department (PED) is responsible for regulation and policy formulation regarding power sector.

The Department was established on 5 July, 2011 on the initiative of the Chief Minister Punjab at the time as a response to the energy crisis and to spearhead the Government of Punjab's efforts to exploit its energy sources and initiate power projects in the public and private sector. The purview of the department is constantly expanding, with more responsibilities and powers being devolved to the provinces in the wake of the 18th Amendment to the Constitution of Pakistan.

The mission of this provincial government agency is "*to enhance Punjab Energy security and fuel economic growth by creating an environment that reliably meet the energy demands of all sectors of Punjab's economy through a sustainable and affordable energy mix and its efficient use*."

Punjab Power Development Board (PPDB)

Referred to as "One Window Facilitator", established by the Punjab Government under the PPDB Act, 2011, and enacted by the Punjab Assembly. Main responsibility of PPDB is to facilitate the private investors on behalf of the Government in matters relating to the setting up of power projects in accordance with the policy of the Government.

Punjab Power Development Company Limited (PPDCL)

A Government of Punjab owned corporate entity duly incorporated under section 32 of Companies Ordinance 1984. The company was established in January, 2008. It is registered with the Security Exchange Commission of Pakistan (SECP), to develop power projects based on different technologies for sale to NTDC or DISCOs. It also looks over supplying quality electric supply in bulk to Industrial Estates or retail electric supply to individual industrial units in Industrial Estates in a commercially viable manner. The main objective is the development of power projects in public sector or in Joint Venture (JV) mode with private sector. It also looks for arranging funding through local banks or international donor agencies or public subscriptions together with Operations and Management (O&M) of power projects in the province.

[11] Official Website of Central Power Purchasing Authority (CPPA-G). Available at: http://www.cppa.gov.pk/Home/CompanyProfile

[12] Official website of Electricity Department. Available at https://electricity.ajk.gov.pk/

Punjab Power Management Unit (PPMU)

PPMU has been established to plan, procure and implement the Asian Development Bank (ADB) funded renewable energy projects. The projects are being implemented on EPC (Engineering Procurement and Construction) mode by inviting International Competitive Bidding (ICB) under the procedures of ADB where contractor is responsible for Engineering, Procurement and Construction.

Khyber Pakhtunkhwa (KP)

The government organizations and departments relevant to power sector are briefly described below.

KP Energy and Power Department (EPD)

The energy portfolio of the provincial government in the Khyber Pakhtunkhwa province is managed by the Energy and Power Department (EPD) and has two technical agencies working under it, the Pakhtunkhwa Energy Development Organization (PEDO) looks after issues relating to electricity generation, transmission and distribution in the province. It is a statutory body functioning under the PEDO Act, 2014, with a corporate structure headed by a Chief Executive Officer reporting to a Board of Directors appointed by the provincial government, including some members from the private sector.

In addition, the EPD contains the office of the Electrical Inspector, appointed under the Electricity Act, 1910, who administers the implementation of the Act and Electricity Rules, 1937, and carries out other regulatory and certification functions under the NEPRA Act, 1997. EPD thus has the authority to grant or revoke licenses to the private sector for engaging in the electricity business, certificates of competency to electrical supervisors, and licenses to electric contractors.

Pakhtunkhwa Energy Development Organization (PEDO)

PEDO's primary functions include identifying and developing the province's hydroelectric potential, constructing and operating small hydro stations for isolated load centers, dealing with relevant federal power sector entities (e.g., WAPDA, NTDC, CPPA-G, PPIB, AEDB, NEPRA, etc.), and providing technical, policy, and planning inputs to EPD.

On the directions of the KP provincial government, PEDO has recently embarked on an ambitious program to construct micro-hydropower projects (<500 kW MHPs) for small, dispersed communities in mountainous terrain, primarily off-grid locations but also some that are grid-connected but routinely subjected to excessive load shedding.

Despite having inherited a mandate and institutional framework going back three decades, PEDO is still in early stages of functional and HR capacity building, having recently undergone organizational restructuring with recruitment of top managers from the private sector on market-based remuneration packages.

A.3
Regulatory Framework for Environmental Protection

Protecting the environment and the ecosystem services in the face of construction and operation of multiple hydropower projects is important to ensure sustainable development. This section outlines the national and provincial regulatory and institutional framework for protecting the environment in the Area of Management.

A.3.1
National Policies and Regulations

The national policies relevant to the environmental conservation and protection are summarized in **Table A-1**.

A.3.2
Provincial and State Statutory and Policy Requirements for Environmental Protection (Punjab, AJK and KP)

The key national environmental legislation was the Pakistan Environmental Protection Act (PEPA 1997). After devolution through the 18th Constitutional Amendment 2010 the provinces have sole authority and responsibility to legislate on 'environment and ecology'.

The laws and regulations for environmental protection in AJK, Punjab and KP are summarized in **Table A-2**.

Table A-1: National Strategies and Policies for Environmental Protection

National Policy	Brief Description
Pakistan Environmental Protection Act, (1997)	The Pakistan Environmental Protection Act, 1997 is the basic legislative tool empowering the government to frame regulations for the protection of the environment. The act is applicable to a broad range of issues and extends to air, water, soil, marine, and noise pollution, as well as to the handling of hazardous wastes. The Act's relevance to biodiversity conservation is primarily through its environmental assessment screening process for proposed projects which makes it mandatory to undertake the environmental assessment prior to initiation of developmental projects and address the biodiversity conservation and protection related issues.
National Environmental Policy (2005)	This policy aims to conserve, restore and manage the environmental resources of the country and provides an overarching framework for addressing environmental issues in Pakistan, particularly pollution of fresh water bodies, air pollution, waste management, deforestation, loss of biodiversity, desertification, natural disasters and climate change. It also gives directions for addressing cross-sectorial issues as well as meeting international obligations, sustainable management of resources, and economic growth.
National Sustainable Development Strategy (2012)	The Strategy is an attempt to define sustainable development and the pathway to a "green economy" in Pakistan's context. It lays out an adaptive system and approach that can be continuously improved, through regular updates, to respond to evolving challenges. The focus has been on integrating not only across the three overall dimensions of economic, social and environment but also integrating the goals with the existing development paradigm with the aim of shifting it on to a more sustainable pathway.
National Climate Change Act (2017)	The National Climate Change Act, approved by the Government in March 2017, has the overall goal 'to ensure that climate change is mainstreamed in the economically and socially vulnerable sectors of the economy and to steer Pakistan towards climate resilient development'. To support the Climate Change Policy, in 2013 the Government prepared a Framework for Implementation of the Climate Change Policy (2014-2030) which lists priority, short-term, medium-term and long-term actions to be implemented in various sectors. One of the energy sector mitigation actions identified in this Framework is the development and enhancement of renewable energy to achieve green growth. Action points with respect to development of hydropower included in the Framework include: • Develop and promote hydropower projects through dams in Khyber Pakhtunkhwa (Short Term) • Develop mechanism to support the Public Private Partnership in mobilizing, financing and enabling investments in hydel-power projects and make sure its implementation through proper legislation (Short Term) • Ensure construction of hydropower structures at appropriate sites in Punjab to cover its power shortfall.
National Water Policy (2018)	The National Water Policy lays down a broad policy framework and set of principles for water security on the basis of which the Provincial Governments can formulate their respective Master Plans and projects for water conservation, water development and water management. The National Water Policy's objectives include, amongst others, efficient management and conservation of existing water resources, optimal development of potential water resources and improved flood control and protective measures.
National Forest Policy (2015)	The goal of the National Forest Policy is the expansion of national coverage of forests, protected areas, natural habitats and green areas for restoration of ecological functions and maximizing economic benefits while meeting Pakistan's obligations to international agreements related to forests.
National Biodiversity Action Plan (2000)	Pakistan is a signatory to the Convention on Biological Diversity (CBD), and was thereby obligated to develop a national strategy for the conservation of biodiversity. The national BAP sets out a strategy for action under 13 main components which correspond to the Articles of the CBD: planning and policies, legislation, identification and monitoring, in-situ conservation, ex-situ conservation, sustainable use, incentive measures, research and training, public education and awareness, EIA, access issues, exchange of information and financial resources. For each component, the issues relevant to Pakistan are identified and a list of objectives and corresponding actions are recommended to deal with the identified issues.
Guidelines for Sensitive and Critical Areas (1997)	The guidelines refer to the identification of officially notified protected areas in Pakistan, including critical ecosystems and archaeological sites. Environmentally sensitive areas include, among others, archaeological sites, biosphere reserves and natural parks, and wildlife sanctuaries and preserves. These guidelines provide guidance in the environmental assessment process so that the proposed projects are planned and sited in a way that protects the values of sensitive and critical areas. The guidelines help in identifying the officially notified protected areas (critical ecosystems including wildlife reserves and forests) and provide a detailed approach that should be adopted if a proposed development is on a notified protected area or within vicinity of such an area.

National Policy	Brief Description
Policy and Procedures for Filing, Review and Approval of Environmental Assessments, Pakistan Environmental Protection Agency (September 1997)	These guidelines define the policy context and the administrative procedures that will govern the environmental assessment process, from the project pre-feasibility stage, to the approval of the environmental report. The section on administrative procedures has been superseded by the IEE-EIA Regulations, 2000.
Wildlife Act (1975)	The Wildlife Act identifies and protects flora and fauna species of concern. It also empowers the Wildlife Department at both provincial and district levels to establish game reserves, parks and wildlife sanctuaries and regulates hunting and disturbance of wildlife.
Indus Water Treaty (1960)	The Indus Waters Treaty is a water-sharing treaty between Pakistan and India, brokered by the World Bank (then the International Bank for Reconstruction and Development). The treaty was signed in Karachi on September 19, 1960 by Indian Prime Minister Jawaharlal Nehru and President of Pakistan Ayub Khan (President of Pakistan). The treaty, envisages the sharing of waters of the rivers Ravi, Beas, Sutlej, Jhelum and Chenab which join the Indus River on its left bank (eastern side) in Pakistan.

Table A-2: Relevant Provincial Laws and Regulations for Environmental Protection

Laws and Regulations	Brief Description
Azad Jammu and Kashmir (AJK)	
The Azad Jammu and Kashmir Environmental Protection Act (2000) (the 'AJK-EPA 2000' or the 'Act')	The AJK Environmental Protection Act 2000 (the 'AJK-EPA 2000' or the 'Act') is the principal legislative tool used for regulating environmental protection in the state of AJK. The responsibility to implement the provisions of the Act lies with the AJK-EPA. There are other instruments (regulations, rules, standards, and guidelines) subservient to the AJK-EPA 2000 which together with the Act form the basic environmental law of AJK.
Jammu and Kashmir Forest Regulations (1930, as amended)	Forests in Pakistan-administered Kashmir are managed according to the guidelines provided in these regulations, generally known as the Forest Law Manual. These regulations set out the rules and regulations for both demarcated and non-demarcated forests, collection of drift and stranded wood as well as penalties and procedures for not abiding by these regulations.
Azad Jammu and Kashmir Environmental Protection Act (2000)	The Azad Jammu and Kashmir Environmental Protection Act, 2000 is the principal legislative tool used for regulating environmental protection in the state of Azad Jammu and Kashmir. The Act is applicable to a broad range of issues and extends to air, water, industrial liquid effluent, and noise pollution, as well as to the handling of hazardous wastes. The responsibility to implement the provisions of the 2000 Act lies with the Azad Jammu and Kashmir Environmental Protection Agency (the 'Agency' or 'AJK-EPA').
AJK Wildlife (Protection, Preservation, Conservation and Management) Act (2014)	The AJK Wildlife (Protection, Preservation and Management) Act 2014 was first promulgated as an Ordinance by the President of AJK in 2010 with an aim to consolidate the laws relating to protection, preservation, conservation and management of wildlife in Azad Jammu and Kashmir. It is aimed at promoting social, economic, cultural and ecological well-being of local communities in conformity with the concerns of the international communities. It outlines the roles and responsibilities of government organizations and departments primarily the AJK Wildlife and Fisheries Department that has the basic responsibility to ensure enforcement of the Act. The ordinance also provides for the declaration of various categories of protected areas. The Ordinance recognizes that it is necessary to fulfil the obligations envisaged under the biodiversity related Multilateral Environmental Agreements ratified by the Government of Pakistan.
Jammu and Kashmir Forest Regulation (1930)	Forests of Azad Jammu and Kashmir are managed according to the guidelines provided by Jammu and Kashmir Forest Regulations of 1930 (including amendments), generally known as Forest Law Manual. This regulation lays down the rules and regulations for both demarcated and un-demarcated forests, collection of drift and stranded wood as well as penalties and procedures for not abiding by these regulations.
Guidelines for Sensitive and Critical Areas adopted by the AJK government	The Pakistan Environmental Protection Agency has issued guidelines for Sensitive and Critical Areas. These guidelines have been adopted by the AJK government and are applicable to sensitive and critical areas in AJK.

Laws and Regulations	Brief Description
Wildlife (Protection, Preservation, Conservation and Management) Ordinance (2013) of Pakistan-administered Kashmir	This Ordinance outlines the roles and responsibilities of government organizations and departments in Pakistan administered Kashmir, primarily the Wildlife and Fisheries Department which is responsible for the enforcement of the Ordinance. It also provides for the declaration of various protected areas: wildlife sanctuaries, wildlife refuges, national parks, game reserves, biosphere reserves, biodiversity reserves and national natural heritage sites. It also prohibits the trade of any wild animal, dead or alive, for domestic or commercial use without a Certificate of Lawful Possession. Permits and trade licenses are necessary for the import, export and trade of wild animals of an endemic or exotic species.
Punjab	
Punjab Environmental Protection Act (1997) (Amended 2012)	In 2012, Punjab promulgated the Punjab Environmental Protection Act 1997 – Amended April.2012 (Punjab Act). The responsibility to implement the provisions of the Punjab Act lies with the Punjab Environmental Protection Department (Punjab EPD) or the Punjab-EPA. The Punjab Act broadly governs regulations over environmental protection including assessment of Environmental Impacts, prohibition of certain discharges or emissions, hazardous materials.
Punjab Forest Act (1927, as amended)	The Act provides the legislation under which forests within the Punjab province are protected. In parts of the reservoir in the Punjab province, the Forest Act shall enforce the overall protection of forests.
Punjab Wildlife Protection, Preservation, Conservation and Management Act (1974); Punjab Wildlife (Protection, Preservation, Conservation and Management) (Amendment) Act (2007)	The 1974 Act is to enforce the overall protection of wild flora and fauna in its natural state in the Punjab province. The Act includes the following schedules: • First Schedule Part I. Wild birds and animals which may be hunted on an ordinary shooting license • First Schedule Part II. Wild animals requiring a special permit for hunting • Second Schedule. Animals, trophies or meat requiring certificate of lawful possession • Third Schedule. Wild birds and animal protected throughout the year • Fourth Schedule. Wild birds and animals which are not protected Under Section 17 of the 2007 Act, national parks are declared for the protection and preservation of flora and fauna in their natural state. The following activities are prohibited in a national park: • Hunting, shooting, trapping, killing or capturing of any wild animal in a national park or within one-and-a-half-mile radius of its boundary • Firing any firearm or doing any other act which may disturb any animal or bird or doing any act which interferes with the breeding places • Felling, tapping, burning or in any way damaging or destroying, taking, collecting or removing any plant or tree therefrom • Clearing or breaking up any land for cultivation, mining or for any other purpose • Polluting water flowing in and through the national park
Fisheries Act (1897), Punjab Fisheries (Amendment) Act (2009) and Punjab Fisheries Ordinance (1961, as amended)	This Act and Ordinance are to enforce the overall protection of fisheries resources through issuance of permits to catch fish. Fish catching is strictly prohibited during the breeding season (March to June).
Khyber Pakhtunkhwa (KP)	
Khyber Pakhtunkhwa Environmental Protection Act (2014)	The KP Environmental Protection Act 2014 is applicable to a broad range of issues and extends to air, water, industrial liquid effluent, and noise pollution, as well as to the handling of hazardous wastes.
The Khyber Pakhtunkhwa Wildlife and Biodiversity (Protection, Preservation, Conservation and Management) Act (2015)	This law was enacted to consolidate the laws relating to protection, preservation, conservation and management of wildlife in KP. It classifies wildlife by degree of protection, i.e., animals that may be hunted on a permit or special license, and species that are protected and cannot be hunted under any circumstances. The Act specifies restrictions on hunting and trade in animals, trophies, or meat. It also defines various categories of wildlife-protected areas, i.e., National Parks, Wildlife Sanctuaries, and Game Reserves.
Forest Ordinance (2002)	The Forest Ordinance, 2002 was enacted to protect, conserve, manage and sustainably develop forests and other renewable natural resources. The Ordinance authorizes provincial forest departments to establish forest reserves and protected forests. It prohibits any person from: setting fires in the forest; quarrying stone; removal of any forest produce; causing any damage to the forest by cutting trees or clearing areas for cultivation; or any other purpose without express permission of the relevant provincial forest department.

Laws and Regulations	Brief Description
Forest Development Corporation Ordinance (1980)	The Forest Development Corporation has been established under this ordinance. The corporation functions to "make suitable arrangements for the (i) economic and scientific exploitation of forests; (ii) sale of forest produce; (iii) establishment of primary wood-processing units; (iv) regeneration in areas to be specified by Government; and (v) performance of such other functions as may be assigned to it by Government."
Forestry Commission Act (1999)	The Act aimed at establishing a Forestry Commission to improve the protection, management sustainable development of forests in KP. Under this Act, the Commission established was empowered and entrusted to further this aim by taking steps such as giving vision and a framework for the sustainable development of forests in KP, overseeing the process of institutional and legislative reforms in the Department, advocating policies for sustainable development of forests etc.
Rivers Protection Ordinance (2002)	The ordinance was instated in view of the increasing developments along the rivers in KP to provide for the protection of aquatic ecology, water quality as well as economic and environmental value of the river and their tributaries in KP. The rules laid out in the ordinance relate mainly to encroachment onto the river and pollution of the river. It is important that Project-related activities do not pollute the river and that all construction activities along the river banks be carried out within the area designated for them.
Integrated Water Resources Management Board Ordinance (2002)	The Integrated Water Resources Management Board has been established to devise and oversee the implementation of an integrated water resources management strategy aimed at sustainable economic, social and environmental returns on water resource development. Under the ordinance, a Board has been established, the functions of which include conducting studies to accurately assess the demands of water for consumptive or non-consumptive use including hydropower generation. The Ordinance also provides guidelines for fisheries, water-related sports, environmental sustainability, forestry, lakes and water bodies.
NWFP Fisheries Rules (1976)	This law prohibits destruction of fish by explosives, poisoning water and the hunting of protected fish species. The law also forbids the use of net or fixed engine traps without a permit or license. The law grants power to the Director General (DG) Fisheries to issue permits to catch fish. It protects fish against destruction of fish by explosives, and by poisoning water.
Islamabad Capital Territory	
Islamabad Wildlife (Protection, Preservation, Conservation, and Management) Ordinance (1979) (Schedule III)	An Ordinance to provide for the protection, preservation, conservation and management of wildlife and setting up of a National park in the Islamabad Capital Territory. This Act consists of 41 sections and 3 Schedules. Sections 9-14 set out provisions on the possession of wild animals, trophies or meat. Schedule III of this Ordinance lists protected species.

A.3.3 Obligations under International Treaties

Pakistan is a party to a number of conventions in relation to biodiversity, including the Convention on the Conservation of Migratory Species of Wild Animals (CMS), the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES), the Convention on Wetlands of International Importance (Ramsar Convention) and the United Nations Convention on Biological Diversity (CBD).

The CBD defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems". As a signatory country, Pakistan has a responsibility to:

- Safeguard its biodiversity.
- Introduce procedures requiring environmental impact assessment (EIA) for projects likely to have significant impacts on biological diversity.
- Introduce legislative provisions that ensure environmental policies and procedures are duly taken into account.

A list of international conventions that focus on biodiversity issues is given in **Table A-3**. With shared goals of conservation and sustainable use of biological resources, the biodiversity-related conventions work to implement actions at the national, regional and international level. In meeting their objectives, the conventions have developed a number of complementary approaches (site, species, genetic resources and/or ecosystem-based) and operational tools (e.g., programs of work, trade permits and certificates, multilateral system for access and benefit-sharing, regional agreements, site listings, funds).

Table A-3: International Agreements on Biodiversity and Status of Entry into Force

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
Bon Convention on Conservation of Migratory Species (CMS)	1979	01 December 1987
Sustainable Development Goals	2015	February 2016
Paris Agreement on Climate Change	2015	November 2016
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal	May 1992	July 1994
International Treaty on Plant Genetic Resources for Food and Agriculture	2004	02 Sep 2003
Convention on Wetlands of International Importance especially as Waterfowl Habitat	1971	23 Nov 1976
Convention Concerning the Protection of the World Cultural and Natural Heritage (WHC)	1972	08 Dec 2011

A.4 Institutional Framework for Environmental Protection

The natural resources within the province of Punjab and KP and the state of AJK, are the responsibility of specific government departments such as wildlife and fisheries departments and forestry departments. Together these form the institutional framework for governance and regulation of natural biological resources. The relevant departments in each province and their roles are described below.

A.4.1 Azad Jammu and Kashmir (AJK)

AJK Wildlife and Fisheries Department (AJKWFD)

The AJKWFD is headed by the Director of Wildlife and Fisheries. The aim of the Department is to "*protect, conserve and manage terrestrial and aquatic wild genetic resources to satisfy need of ecosystems and communities, on sustainable basis, through setting of a protected areas network, habitat protection / development, eco-tourism promotion and promotion of public private partnerships*." The objectives of the Department are as follows:

- Promote eco-tourism through development of safaris, trophy hunting, sport hunting and checking illegal hunting.
- Enhancing the technical capabilities of the department by reorganizing and providing the technical staff in each district of AJK.
- Identifying more potential areas of biodiversity hotspots and establishing new protected areas for proper conservation and management.
- Preparation of Management Plans for each Protected Area and their effective implementation.
- Setting up of a well-designed monitoring system based on the measurable impact and performance indicators to ensure the sustainability of the biological diversity.
- Identification of the custodian communities dependent on the natural resources of the protected areas, organizing them and involving them in the conservation and management practices.
- Reduce the pressure of the custodian communities on the natural resources through the provision of alternate livelihood resources and reduce poverty by initiating activities of income generation.
- Survey of fish diseases and establishment of diagnostic laboratory.

AJK Forest Department

The AJK Forest Department is headed by the Chief Conservator Forests. The aim of the Department is "*scientific management of forestry resource on a sustainable basis, ensuring environmental amelioration, checking sediment inflow into water bodies*." The salient features of present forest management are to:

- Maintain and improve the existing forest for the purpose of soil and water conservation.

- Bring the partially stocked forest to its full capacity by natural as well as artificial regeneration measures.
- Extract the forest according to the principles of forest health.
- Provide the legitimate requirements of local population for grazing and other forest produce.
- Maximize the production without causing permanent damage to the forest crop.
- Improve existing conditions of rangelands and wildlife habitat.
- Create a balance between the utilization of forest resource and the conservation of its environment.

AJK Environmental Protection Agency (EPA)

AJK Environmental Protection Agency was established in July 1998 under the AJK Environmental Protection Act 2000, to provide for the protection, conservation, rehabilitation and improvement of the environment for the prevention and control of pollution and promotion of sustainable development. Presently AJK-EPA, is headed by the Director General of AJK-EPA, with its Head Office at Muzaffarabad.

Environment Unit was established in June 1994 under Northern Resource Management Project (NRMP) in Planning & Development Department (P&DD) headed by an Environmentalist (B-18). This Environmental Unit started its work in July 1994 on following three areas:

- To address and resolve the environmental issues of the State AJK.
- To work out the establishment of Provincial EPAs type State Environmental Protection Agency (AJK-EPA).
- To take initiative of the Government for the promulgation of Environmental Protection Ordinance in AJK.

The proponent is responsible for preparing the complete environmental documentation required by the AJK-EPA and remain committed for getting clearance (No Objection Certificate) from it. Moreover, it is also desirable that once clearance from AJK-EPA is obtained, the proponent should remain committed to the approved project design. No deviation is permitted in design and scope of rehabilitation during project implementation without the prior and explicit permission of the EPAs.

A.4.2 Punjab

Punjab Forest Department

The Forest Department is headed by the Secretary Forest Department. The mission of the Forest Department is to conserve, develop and manage forest resources on a sustainable basis to contribute to the socio-economic development of present and future generations. The Punjab Forest Department is responsible for performing the following functions:

- Preparation and implementation of policies and programs in forestry sector. Implementation of Forestry Laws and rules.
- Protection, conservation, development and management of renewable natural resources, particularly forests and range lands in the province.
- Sustainable management of forests for production of timber, firewood and other non-timber produce and services.
- Demarcation and protection of forest lands against encroachment.
- Raising of nurseries and plantations.
- Provide extension services for mass awareness and conduct research and training for capacity building.

Punjab Wildlife and Parks Department

The Punjab Wildlife and Parks Department is headed by the Director General, Wildlife and Parks, Punjab. The mission of the Department is to protect, preserve, conserve and manage wildlife diversity, habitats and ensure its sustainable development. The main functions of the Department are:

- Protection, conservation, preservation and management of wildlife.
- Management of protected areas, wildlife parks, safaris & zoos.
- Public and private participation through trophy hunting, private breeding farms & hunting associations.

The Punjab Wildlife Protection, Preservation, Conservation and Management Act 1974 law includes legislation pertaining to national parks. Under this Act the following is stipulated for national parks:

- A national park shall be accessible to public for recreation, education and research subject to such restrictions as imposed by the Government.

- Provision for access roads and construction of rest houses, hostels and other buildings in the national park along with amenities for the public may be made and the forest within the national park will be managed so as to not impair the object of the establishment of the national park.
- The government to declare alteration in the boundaries of a wildlife sanctuary, national park and game reserve established under this Act.

Punjab Fisheries Department

The Punjab Fisheries Department is headed by the Director General Fisheries. The mission of the Department is to conserve, manage and develop aquatic resources to meet the quality protein requirements of the masses. The functions of the Department are:

- Extension services/fish farming/aquaculture development.
- Conservation, management and development of natural resources.
- Production of fish seed under controlled conditions.
- Research & Training activities.
- Introduction of new technologies for enhancing fish production.

The Punjab Fisheries Ordinance, 1961 stipulates the following with respect to sanctuaries for fish:

- The government may, by notification, declare any water to be sanctuary for fish mentioned in the First Schedule for a period which may be specified and during which no person shall kill, capture or possess such fish without a special permit issued under this Ordinance by the Director General of Fisheries.
- The water in respect of this notification shall be demarcated in such manner as may be prescribed.

Punjab Environmental Protection Agency

The Environmental Protection Agency of Punjab (EPA Punjab) was formed on July 1, 1987. On December 31, 1996 a separate administrative unit, called the Environment Protection Department (EPD) was formed under the Government of Punjab. The EPA Punjab works as a functional unit under the EPD. On February 11, 1997 the Federal Government withdrew the existing Pakistan Environmental Protection Ordinance (PEPO) of 1983 and declared the Pakistan Environmental Protection Act (PEPA) 1997. The EPA Punjab now undertakes functions as delegated under this Act. The EPA Punjab is headed by a Secretary.

The EPA Punjab's major functions include:

- Administration and implementation of the provisions of Environment Protection Act and the rules and regulations made thereunder.
- Preparation and establishment thereunder Punjab Environmental Quality Standards (PEQS) with approval of the Council and Enforcement.
- Taking measures to promote research and development of science and technology which may contribute to the prevention of pollution, protection of the environment and sustainable development.
- Identifying the needs for, and initiate legislation in various sectors of the environment.
- Providing information and guidance to the public on environmental matters.
- Specifying safeguards for the prevention of accidents and disasters which may cause pollution.
- Encouraging the formation and working of non-government, community and village organizations to prevent and control pollution and promote sustainable development.
- Taking all necessary measures for protection, conservation, rehabilitation and improvement of the environment, and for prevention and control of pollution.
- Promotion of sustainable development.

A.4.3 Khyber Pakhtunkhwa (KP)

Wildlife Department, KP

The Forestry, Environment, and Wildlife Department of Khyber Pakhtunkhwa (referred to as Wildlife Department, KP) is headed by the Chief Conservator Wildlife, KP. The Department enforces the provisions of the Khyber Pakhtunkhwa Wildlife and Biodiversity Act, 2015 to meet its objectives which include strengthening the administration of the organization to effectively manage wild animals and their habitats, to fulfil the obligations of the government under its commitments to managing biodiversity, and promote public awareness for the value of wildlife and conservation. All wildlife is under the jurisdiction of this department.

While protection of fish is in the mandate of the Fisheries Department, legally all the other aquatic wildlife including macro-invertebrates, periphyton, and aquatic habitats fall in the mandate of the Wildlife Department.

Fisheries Department, KP

The Fisheries Department, KP falls under the Agriculture, Livestock and Cooperatives Department of the province. It is headed by the Director Fisheries and represented by District Officer Fisheries in each district. It has the authority to enforce the laws and regulations provided in the Fisheries Rules, 1976. This includes regulation of fishing methods using permits and licenses, the species that can be caught and associated penalties for violation of regulations pertaining to wild fish. All wild fish fauna is under the jurisdiction of the Fisheries Department.

Forest Department, KP

The Forest Department, KP is headed by Conservator Forest with Divisional Forest Officer in each district. Since its inception, Forest Department has been working for development and promotion of forestry, soil conservation works, watershed management, wildlife conservation and sericulture/moriculture.

The Forest Department enforces the provisions of the Forest Ordinance, 2002 to meet its objectives which include protection, conservation, management and sustainable development of forests by engaging the community and defining the role of the government. All forest areas including reserved forests, village forests, protected forests, guzara forests and wastelands, and produce from forests, is under the jurisdiction of this department.

Environmental Protection Agency (EPA), KP

The KP EPA was established in 1989. It is a monitoring and regulating agency with the following main functions:

- Administer and implement the KP Environmental Protection Act 2014, its rules and regulations.
- Review the Initial Environmental Examination – Environmental Impact Assessment (IEE-EIA), including preparation of procedures and guidelines.
- Preparation, revision and enforcement of National Environmental Quality Standards (NEQS) (industries, municipalities and vehicular emissions).
- Establish and maintain laboratories, certification of laboratories, for conducting tests and analysis.
- Assist local councils/authorities and government agencies in execution of projects.
- Establish a system for surveys, monitoring, examination and inspection to combat pollution.
- Conduct training for government functionaries and industrial management.
- Provide information and education to the public on environmental issues.
- Publish an annual state of the environment report. Survey qualitative and quantitative data on air, soil, water, industrial/municipal and traffic emissions.
- Take measures to promote environment related research and development activities.

A.5
International Finance Corporation (IFC) Performance Standards

The IFC, established in 1956, is known as the private sector arm of the World Bank Group. IFC's Environment and Social (E&S) requirements for projects are established in IFC's Policy on Environmental and Social Sustainability and embodied within the eight Performance Standards (PS) of 2012.

International Finance Corporation applies the Performance Standards to manage social and environmental risks and impacts and to enhance development opportunities in its private sector financing in its member countries eligible for financing. Together, these Performance Standards establish standards that the client is required to meet throughout the life by IFC or other relevant financial institution.

- Performance Standard 1: Social and Environmental Assessment and Management System
- Performance Standard 2: Labor and Working Conditions
- Performance Standard 3: Pollution Prevention and Abatement
- Performance Standard 4: Community Health, Safety and Security
- Performance Standard 5: Land Acquisition and Involuntary Resettlement
- Performance Standard 6: Biodiversity Conservation and Sustainable Natural Resource Management
- Performance Standard 7: Indigenous Peoples
- Performance Standard 8: Cultural Heritage

These standards are internationally accepted and recognized to manage social and environmental risks and impacts.

Projects funded by IFC in Pakistan are obligated to meet the IFC standards during Project design, construction and operation. However, other project developers (of hydropower or developmental projects) are not legally bound to meet these standards.

A.6
ADB's Safeguard Policy Statement 2009

Built upon the three previous safeguard policies on the Involuntary Resettlement Policy (1995), the Policy on Indigenous Peoples (1998) and the Environment Policy (2002), the Safeguard Policy Statement was approved in 2009.[13] The safeguard policies are operational policies that seek to avoid, minimize or mitigate adverse environmental and social impacts including protecting the rights of those likely to be affected or marginalized by the developmental process.

'Borrowers/clients' of ADB are obligated to show compliance with the Safeguard Policy. However, it is not mandatory for other project developers in the country to meet the requirement of this policy.

A.7
Hydropower Sustainability Guidelines

The International Hydropower Association (IHA) formed under the support of UNESCO in 1995, began work on the IHA Sustainability Guidelines on Good International Industry Practice.[14] These Guidelines considered the strategic priorities, as well as World Bank Safeguard Policies, International Finance Corporation Performance Standards, and the Equator Principles. The Hydropower Sustainability Guidelines define expected sustainability performance for the hydropower sector across a range of environmental, social, technical and governance topics. The 26 guidelines present definitions of the processes and outcomes relating to good practice in the planning, operation and implementation of hydropower projects. As a compendium, the guidelines are a reference document for meeting the expectations of lenders, regulators, and consumers.

The Hydropower Sustainability Assessment Protocol (HSAP) is a tool for assessing projects across a range of social, environmental, technical and economic criteria. The assessment protocol provides an international common language on how these criteria can be addressed at all stages of a project's lifecycle: planning, preparation, implementation and operation.

A.8
World Commission on Dams (WCD) Guidelines

The World Commission on Dams (WCD) established the most comprehensive guidelines for dam building.[15] The WCD's final report describes an innovative framework for planning water and energy projects that is intended to protect dam-affected people and the environment, and ensure that the benefits from dams are more equitably distributed.

The WCD framework covers key areas for improved planning of dams, including the need to fully assess all available options for meeting water and energy needs; addressing outstanding social issues from existing dams before building new ones, gaining public acceptance for key decisions, and the importance of protecting healthy rivers. The WCD recommendations form the basis for many decision-making processes for dams around the world and constitute international soft law. They are also being adapted to national contexts in various public dialogue processes around the world.

The Commission lists seven strategic priorities for an equitable and sustainable development of water and energy resources.

- Gaining public acceptance
- Comprehensive options assessment
- Addressing existing dams
- Sustaining rivers and livelihoods
- Recognizing entitlements and sharing benefits
- Ensuring compliance
- Sharing rivers for peace, development and security

All seven strategic priorities are supported by a key message and policy principles. They form the basis of the WCD Criteria and Guidelines.

[13] Asian Development Bank. 2009. Safeguard Policy Statement, Policy Paper.

[14] International Hydropower Association Limited. 2018. Hydropower Sustainability Guidelines on Good International Industry Practice

[15] World Commission on Dams. 2000. Dams and Development: A New Framework for Decision Making.

Annex B

Stakeholder Identification and Mapping

Stakeholders are groups or individuals that can affect or take affect from a project's outcome. ADB SPS 2009[1] and IFC Performance Standards[2] specifically identifies affected people, concerned non-governmental organizations (NGOs) and government, as prospective stakeholders to a project. This section identifies the institutional stakeholders, particularly from the government, which are relevant to sustainable hydropower development in the Jhelum-Poonch basin.

B.1
Objectives of Stakeholder Analysis

The objective of the stakeholder analysis, described in this document, is to:

- Identify the major institutional stakeholders that have interest in sustainable hydropower development in the Area of Management
- Differentiate between primary and secondary stakeholders based on their level of influence and interest

B.2
Methodology

Following is the methodology used for the identification and analysis of institutional stakeholders:

- The institutional stakeholders from government departments, NGOs and civil society organizations from the Area of Management were identified based on a literature review of relevant websites as well as previous ESIAs completed in the basin (**Section 1.7**, *Sources of Information in Strategy for Sustainable Hydropower*).
- The level of interest and influence of the stakeholders was determined based on the questions below. If the answer was 'yes' to three or more of the seven questions below, the stakeholder was identified as primary stakeholders while the rest were categorized as secondary stakeholders.
    - ¤ Does this stakeholder have any past, present or planned involvement in hydropower development and/or environmental and social management in Area of Management?
    - ¤ Will this stakeholder promote/support sustainable hydropower development, provided that they are involved?
    - ¤ Will this stakeholder obstruct/hinder sustainable hydropower development if they are not involved?
    - ¤ Does the stakeholder have a legal mandate to promote environmental conservation in AoM?
    - ¤ Is this stakeholder directly responsible for decisions on issues important to hydropower development or environmental conservation in AoM?
    - ¤ Do the stakeholder's goals and expectations either support or conflict with sustainable hydropower development goals in AoM?
    - ¤ Does the stakeholder have the ability to mobilize civil society in pursuit of its objectives?

A list of the institutional stakeholders, and whether they are primary or secondary stakeholders, is provided in **Table B-1**.

Table B-1: List of Identified Institutional Stakeholders in Area of Management

No.	Institutional Stakeholder	Abbreviation	Type	Importance
	National/Federal			
1.	Ministry of Climate Change	MoCC	Government	Secondary
2.	Planning Commission of Pakistan	PCP	Government	Secondary
3.	National Electric Power Regulatory Authority	NEPRA	Government	Primary
4.	National Transmission & Despatch Company	NTDC	Government	Secondary
5.	Environmental Protection Agency	Pak-EPA	Government	Primary
6.	Ministry of Energy	MoE	Government	Secondary
7.	Water and Power Development Authority	WAPDA	Government	Primary
8.	Private Power and Infrastructure Board	PPIB	Government	Secondary
9.	Alternative Energy Development Board	AEDB	Government	Secondary
10.	World Wide Fund for Nature- Pakistan	WWF-P	NGO	Primary
11.	International Union for Conservation of Nature	IUCN-P	NGO	Primary

[1] Asian Development Bank (ADB). 2009. Safeguard Policy Statement
[2] International Finance Corporation (IFC). 2012. IFC Performance Standards

No.	Institutional Stakeholder	Abbreviation	Type	Importance
	Azad Jammu Kashmir			
12.	Power Development Organization	PDO-AJK	Government	Primary
13.	Private Power Cell, AJK	AJKPPC	Private	Primary
14.	Electricity Department,AJK	ED-AJK	Government	Primary
15.	Wildlife and Fisheries Department, AJK	AJKWFD	Government	Primary
16.	Environmental Protection Agency	EPA-AJK	Government	Primary
17.	Forest Department, AJK	FD-AJK	Government	Primary
18.	Planning and Development Department, AJK	P&DD-AJK	Government	Secondary
19.	Board of Revenue	BoR-AJK	Government	Secondary
20.	Industries, Commerce, Mineral Resources and Labor Department, AJK	ICML-AJK	Government	Secondary
21.	Public Works Department, AJK	PWD-AJK	Government	Secondary
22.	Finance Department, AJK	FD-AJK	Government	Secondary
23.	Tourism and Archaeology Department	TAD-AJK	Government	Secondary
	Punjab			
24.	Punjab Energy Department	PED	Government	Primary
25.	Punjab Power Development Board	PPDB	Government	Primary
26.	Punjab Power Development Company Limited	PPDCL	Government	Primary
27.	Punjab Power Management Unit	PPMU	Government	Primary
28.	Punjab Forest Department	FrD-P	Government	Primary
29.	Punjab Fisheries Department	FiD-P	Government	Primary
30.	Punjab Environmental Protection Agency	EPA-P	Government	Primary
31.	Planning and Development Department, Punjab	P&DD-P	Government	Secondary
32.	Board of Revenue, Punjab	BoR-P	Government	Secondary
33.	Punjab University	PU	Academic	Secondary
34.	National University of Science and Technology	NUST	Academic	Secondary
35.	Mines and Minerals Department, Punjab	MMD-P	Government	Secondary
36.	Public Works Department, Punjab	PWD-P	Government	Secondary
37.	Finance Department, Punjab	FD-P	Government	Secondary
38.	Tourism Development Corporation of Punjab	TDCP	Government	Secondary
39.	Directorate of Archaeology Punjab	DA-P	Government	Secondary
	Khyber Pakhtunkhwa			
40.	Energy and Power Department, KP	EPD-KP	Government	Primary
41.	Pakhtunkhwa Energy Development Organization	PEDO	Government	Primary
42.	Wildlife Department, KP	WL-KP	Government	Primary
43.	Fisheries Department, KP	FiD-KP	Government	Primary
44.	Forest Department, KP	FrD-KP	Government	Primary
45.	Environmental Protection Agency, KP	EPA-KP	Government	Primary
46.	Planning and Development Department, KP	P&DD-KP	Government	Secondary
47.	Board of Revenue, KP	BoR-KP	Government	Secondary
48.	Peshawar University	PrU	Academic	Secondary
49.	Mines and Minerals Development, KP	MMD-KP	Government	Secondary
50.	Finance Department, KP	FD-KP	Government	Secondary
51.	Tourism Corporation, KP	TC-KP	Government	Secondary
52.	Directorate of Archaeology and Museums, KP	DA-KP	Government	Secondary

Annex C

Overview of Physical Conditions

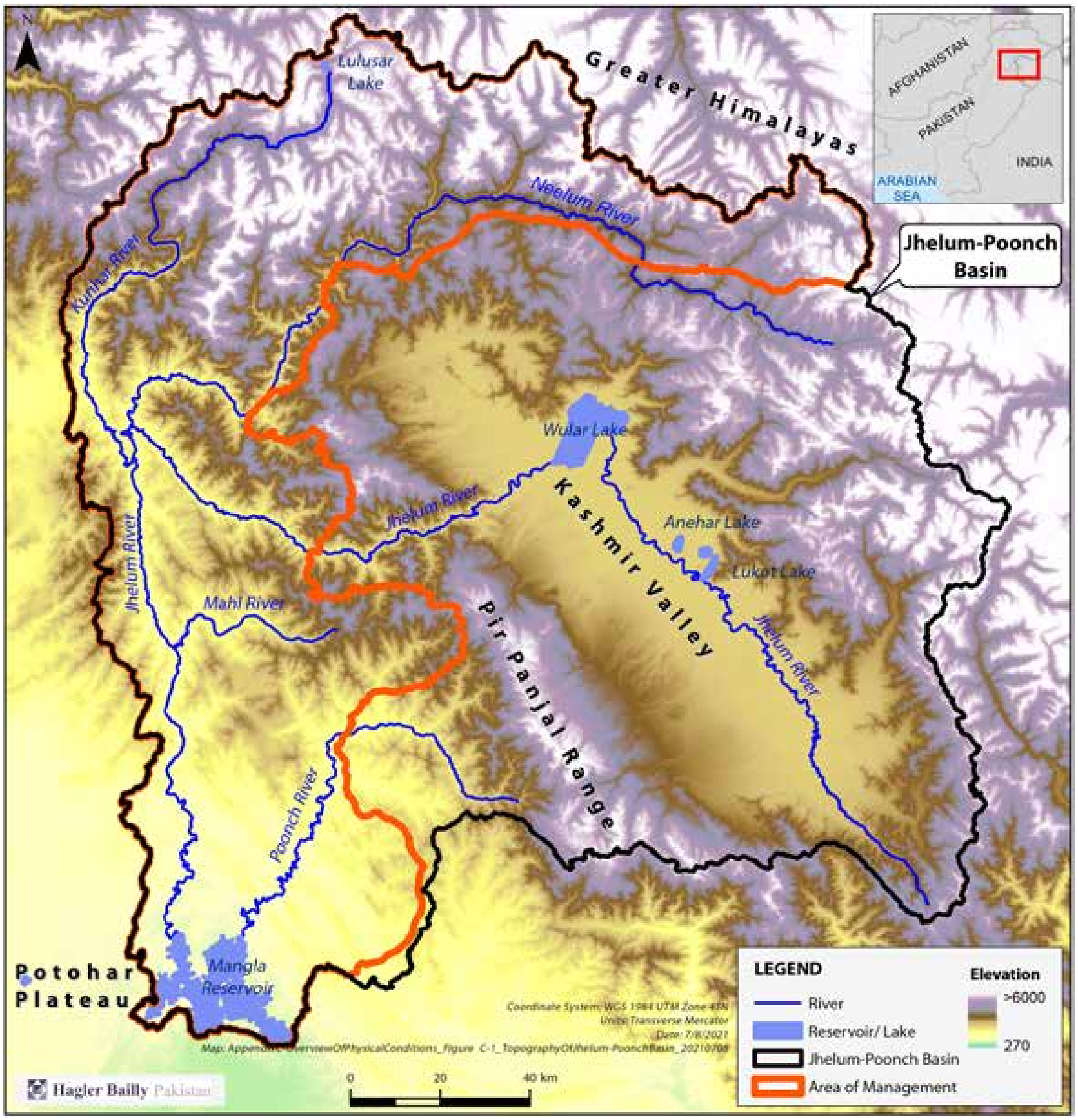
This section provides an overview of the physical conditions in the Jhelum-Poonch basin with a focus on the Area of Management (**Section 1.3**, *Area of Management in Strategy for Sustainable Hydropower Development*).

C.1 Topography

The catchment topography for the Jhelum River catchment up to Mangla dam is shown in **Figure C-1**. The area falls at the western edge of the Higher Himalaya range. Based on the topography, the catchment area can be subdivided into four units as follows[1]:

1. Alpine area at the north most area of this region, with an altitude of approximately 3,500 m.
2. Medium and high mountain area in the northern and central part of this region, with an altitude of approximately 2,000 m; to the east is Kashmir Basin, and to the west is Pansavart Basin.
3. Low to medium mountain area in the central part of this region; to the west is Potohar plateau with the altitude of approximately 500 m, and to the east is Hazara- Kashmir-syntaxis with an altitude of approximately 2,500 m.
4. Plain area towards the south of this region, with the altitude of approximately 200 m.

Figure C-1: Topography of Jhelum-Poonch Basin



[1] Hagler Bailly Pakistan (HBP). 2018. *Environment and Social Impact Assessment of Mahl Hydropower Project* for Shanghai Investigation Design & Research Institute Co. Ltd., Islamabad

C.2
Geology, Soils and Seismicity

This section presents information on the geology, soils and seismicity in the Area of Management.

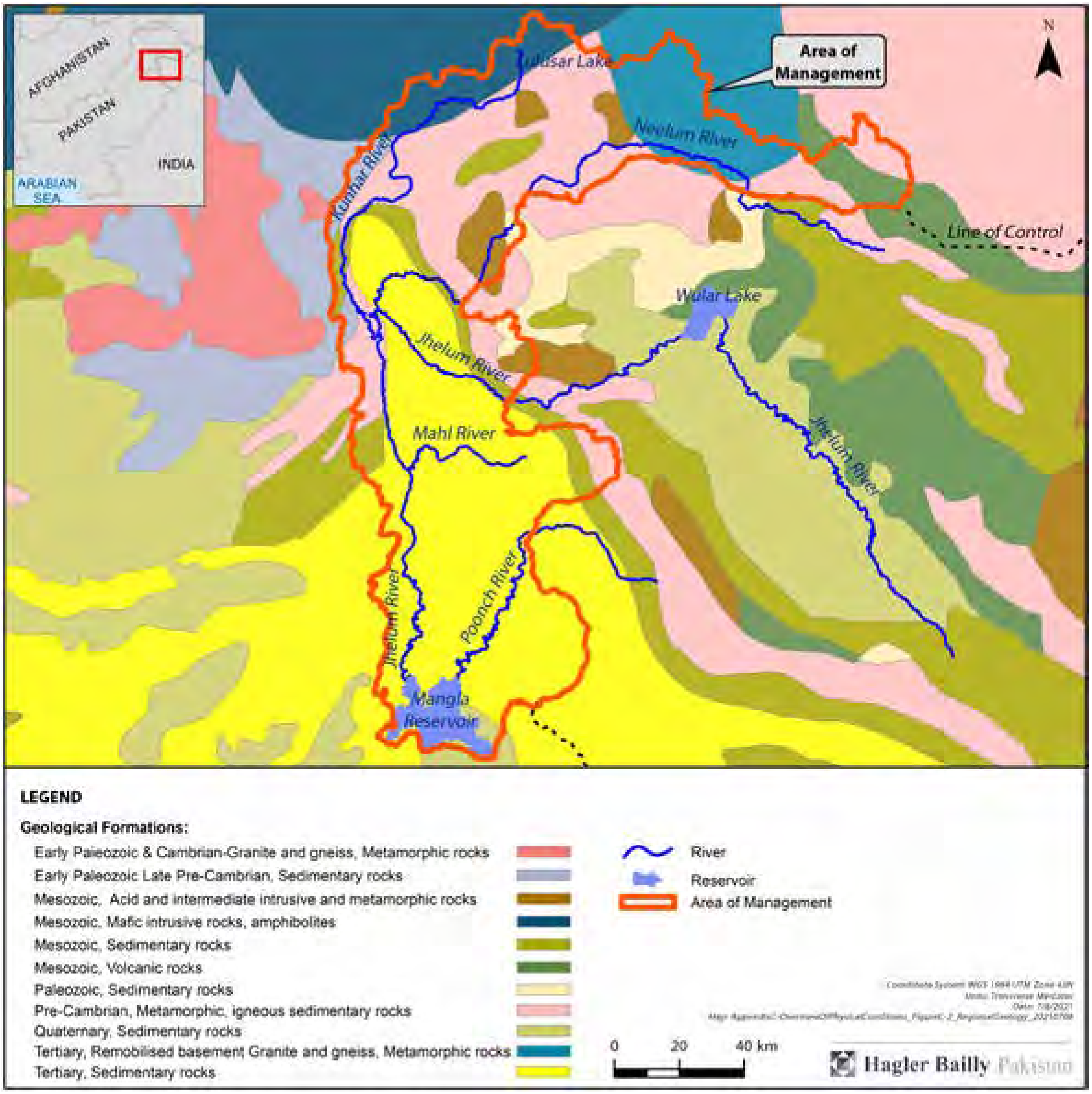
C.2.1
Lithology

The Area of Management is located on the Himalayan thrust nappe. Most of the strata in the north of the area consists of Pre-Cambrian Metamorphic Igneous Sedimentary rocks while the southern part of the Area of Management is dominated by Tertiary Sedimentary rocks. Other rocks include Mesozoic Sedimentary rocks as well as Mesozoic Acid and Intermediate Intrusive and Metamorphic rocks. A map of the regional geology is presented in **Figure C-2.**

C.2.2
Tectonics

The Area of Management is located in a seismically active zone affected by the continuing northward drifting of the Indian plate and its subduction below the Eurasian plate. A number of regional and local faults are known to be active in the area. It is located at the southern foot of Himalayas. The Himalaya is the world's youngest and largest orogenic belt formed by the collision between the Indian plate and the Eurasian plate. There are region syntaxis with sharp turns at both the east and west ends of the Himalaya. The western syntaxis consists of the following tectonic units (from north to south): the Karakorum Plate, Karakorum Suture Zone (extends westwards into the Indus River-Yarlung Zangbo River suture zone), Kohistan-Ladakh Island Arc, Indus River-Yarlung Zangbo River suture zone and Nanga Parbat-

Figure C-2: Regional Geology



Haramosh Massif, the faults at the primary boundary of Himalaya, and the Hazara–Kashmir Syntaxis.

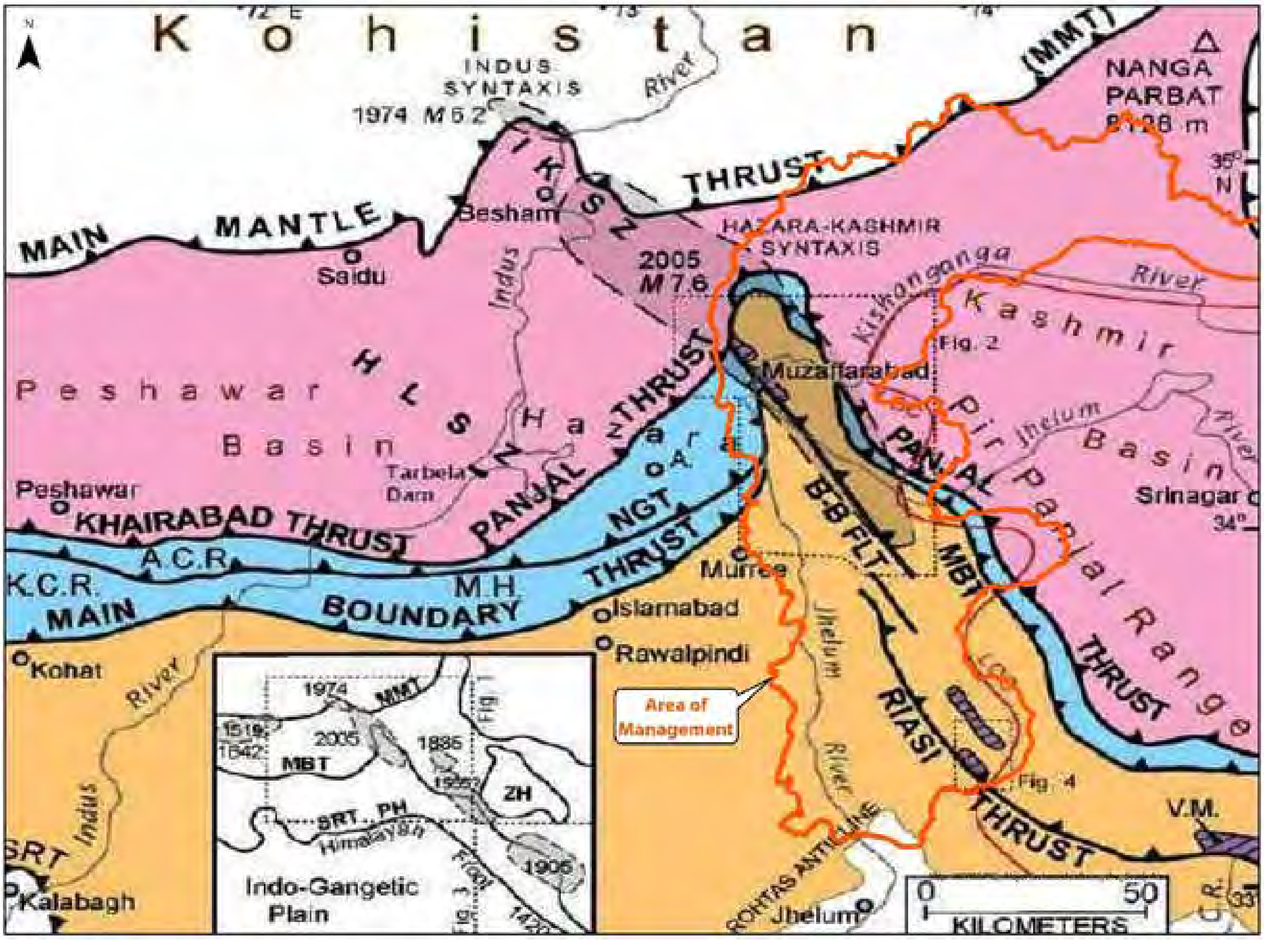
The major regional thrust faults related to intercontinental collision include Main Mantle Thrust (MMT), Main Boundary Thrust (MBT), Panjal Thrust (PT), Main Central Thrust (MCT), and Himalayan Frontal Thrust (HFT). These faults are illustrated in **Figure C-3**. The planes of these faults run nearly parallel to the collision boundary.

C.2.3 Earthquakes and Seismicity

The depth of the earthquake focus in this region is mainly within 1 to 250 km. Most of the earthquakes are moderate to deep-focus earthquakes. The region is located where the Indian plate collided with the Eurasian plate.

For seismic safety evaluation of the Mahl Hydropower Project, a catalogue of earthquakes was compiled for the region extending over a radius of 300 km from the project site in the feasibility study[3] (**Table C-1**). This covers a large part of the Area of Management. Both the historic and recent instrumental recorded data were compiled for the period AD 1555 to 2014. The data was obtained from the International Seismic Catalogue ISC UK, Word Earthquake Catalogue of NEIC USA, and the 'Historical Earthquake Catalogue' prepared by the Pakistan Meteorological Department (PMD). The catalogue included 1,554 earthquakes within the

Figure C-3: Major Tectonic Faults in Area of Management[2]



[2] Hussain, Ahmad, Robert Yeats, and MonaLisa. 2009 "Geological setting of the 8 October 2005 Kashmir earthquake." *Journal of Seismology* 13.3: 315-325; Notes: A.C.R., Attock–Cherat Range; K.C.R., Kala Chitta Range; M.H., Margalla Hills; B-B FLT, Balakot–Bagh fault; IKSZ, Indus Kohistan Seismic Zone; HLSZ, Hazara–Lower Seismic Zone; NGT, Nathia Gali thrust; HFT, Himalayan Front thrust; SRT, Salt Range thrust; PH, Pabbi Hills; A, Abbottabad; ZH, Zanskar Himalaya; diagonal pattern: Precambrian limestone inliers. Shaded pattern, meizoseismal zones of earthquakes with dates give; shading in main map shows the 2005 earthquake.

[3] Shanghai Investigation, Design & Research Institute Co. Ltd. in association with Associate Consulting Engineers and Mirza Associates Engineering Services. (2017). *Mahl Hydropower Project Feasibility Report, Volume I Main Report* for the China Three Gorges International Corporation

region, of magnitude M > 4.0 with focal depth of not more than 50 km (or unknown depth). During the record period, the strongest earthquake of magnitude 8.0 occurred at Kangra, India in 1905, followed by magnitude 7.6 earthquake in Kashmir in 2005.

Table C-1: Distribution of Earthquake Events (M> 4.0) in Order of Magnitude

Magnitude	Number of Events
4.0 – 4.9	1,328
5.0 – 5.9	204
6.0 – 6.9	18
7.0 – 7.9	3
8.0 – 8.9	1
Total	**1,554**

C.2.4 Landslides

Heavy rainfall and associated flooding increase the risk of landslides. According to information provided in the Environmental and Social Impact Assessment (ESIA) of Mahl Hydropower Project,[4] local communities reported that the incidence of landslides following heavy rainfall, particularly after the 2005 earthquake has increased. Moreover, during the physical field surveys carried out in July 2017 for this study, numerous landslides, of quaternary soil deposits, were observed following relatively heavy rainfall (**Figure C-4**).

C.3 Climate

This section provides an overview of the climate in the Jhelum-Poonch Basin. The following four seasons can be identified:

Summer (mid-March to mid-June)

Characterized by high temperatures, moderate rainfalls with moderate humidity and high speed-winds.

Summer Monsoon (mid-June to mid-September)

The summer monsoon, hereafter referred to as the Monsoon, is characterized by high temperatures (although milder than the summer), significantly high rainfalls with high humidity and moderate speed-winds, slightly lower than summers.

Post-Monsoon summer (mid-September to mid-November)

Characterized by moderate temperatures, low rainfalls with moderate humidity, as the humidity again reduces after monsoon and low speed-winds.

Winter (mid-November to mid-March)

Characterized by very low temperatures, moderate rainfalls, with an increasing amount of rainfall at the end of the winter, with relative humidity greater than post-monsoon summer and moderate speed-winds.

Figure C-4: Landslides near the proposed site of Mahl HPP[5]

Sealed road covered with mud post landslide.

Landslide prone areas near Project reservoir.

[4] Hagler Bailly Pakistan (HBP). 2018. *Environment and Social Impact Assessment of Mahl Hydropower Project* for Shanghai Investigation Design & Research Institute Co. Ltd., Islamabad

[5] Ibid

C.3.1 Temperature and Precipitation

This section provides an overview of the temperature and precipitation of the Jhelum-Poonch Basin. Information is derived from the WorldClim 2.0 dataset.[6] The WorldClim dataset is more representative of the catchment compared to point gauging data, as it is a gridded dataset, and it utilizes a large regional network of gauges and co-variates including elevation and distance to the coast, as well as satellite covariates (maximum and minimum land surface temperature and cloud cover).[7]

An evaluation of the mean monthly temperatures in the sub-basins of the Jhelum-Poonch basin (**Table C-2**) shows:

- Neelum basin is the coldest sub-basin with mean monthly winter temperatures falling as low as -8°C and the mean monthly maximum summer temperature ranging between 14 – 15 °C.
- In the Kunhar basin, the coldest temperatures are experienced from December to February where the mean monthly temperature can fall as low as -6°C, while the maximum mean monthly temperatures are experienced in the months of June, July and August (14 to 16°C).
- In the Middle Jhelum Basin, the mean monthly temperature varies from 1°C in the month of January, to 21°C in June, July and August.
- In the Upper Jhelum Basin, the mean monthly temperature varies between -3°C and 18°C.
- The Poonch Basin is a comparatively warmer basin with the mean monthly temperature ranging from 5°C (in January) to 24°C (in June and July).
- In the Lower Jhelum basin, the mean monthly temperature varies from 8°C in January to 28°C in June.

The Jhelum-Poonch Basin lies at the edge of the core monsoon region[8] of Pakistan and western Himalaya, experiencing the South Asian Summer Monsoon (SASM)[9] in summer. Due to orography as well as the region being at the northwestern extent of the SASM, there are two distinct SASM precipitation regimes in Jhelum-Poonch Basin.[10] In the northern part of the Jhelum-Poonch Basin, there is a single peak in spring (SASM) precipitation or the summer (also SASM) peak is weakly developed. In the southern part, the monsoon rains dominate and the summer peak is better developed.[11]

The temperature and precipitation data for the Jhelum-Poonch Basin is summarized in **Figure C-5** to **Figure C-8**.

The differences between the upper and lower catchment, in terms of temperatures and SASM precipitation, are evident in **Figure C-5** (all months) and **Figure C-6** (particularly July and August). The SASM precipitation in the Jhelum-Poonch Basin begins around mid to late-June, peaks in July and August, and begins to recede albeit slowly from start of September. By end of September the SASM has completely receded from most of Pakistan and India.

Over the Karakoram and western Himalaya, winter precipitation is mainly received from westerly flows embedded in mid-latitude cyclones, regionally called as "western disturbances. The western disturbances affect the Naran basin November through May (see winter precipitation in **Figure C-6** and **Figure C-8**). However, these disturbances do not extend into the entire Jhelum-Poonch Basin (e.g. in Upper Jhelum Basin). Since the winter precipitation is positively related to elevation the catchment precipitation is postulated to be significantly greater than the available measurements (i.e. station data), at least for winter.[13]

The gridded dataset shows a positive relationship between winter precipitation and elevation. In addition, the lower catchment has higher precipitation in summer (see discussion above on two climatic regimes related to the SASM). Similarly, catchment average elevation, e.g. Balakot and Poonch which are at greater elevation, are related to lower temperatures as expected.

[6] Fick, S.E. and R.J. Hijmans, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*.

[7] Satellite co-variates marginally improve the dataset and ground-based weather station data is of more value.

[8] Latif, M., & Syed, F. (2015). Determination of summer monsoon onset and its related large-scale circulation characteristics over Pakistan. *Theoretical and Applied Climatology*, 125(4), 509-520.

[9] Also known as the South-West Monsoon

[10] Archer, D., & Fowler, H. (2008). Using meteorological data to forecast seasonal runoff on the River Jhelum, Pakistan. *Journal of Hydrology*, 361(1), 10-23.

[11] Archer, D., & Fowler, H. (2008). Using meteorological data to forecast seasonal runoff on the River Jhelum, Pakistan. *Journal of Hydrology*, 361(1), 10-23.

[12] Palazzi, E., Hardenberg, J., & Provenzale, A. (2013). Precipitation in the Hindu-Kush Karakoram Himalaya: Observations and future scenarios. *Journal of Geophysical Research: Atmospheres*, 118(1), 85-100.

[13] Archer, D., & Fowler, H. (2008). Using meteorological data to forecast seasonal runoff on the River Jhelum, Pakistan. *Journal of Hydrology*, 361(1), 10-23.

Figure C-5: WorldClim Gridded Temperature (1970-2000) for Jhelum-Poonch Basin

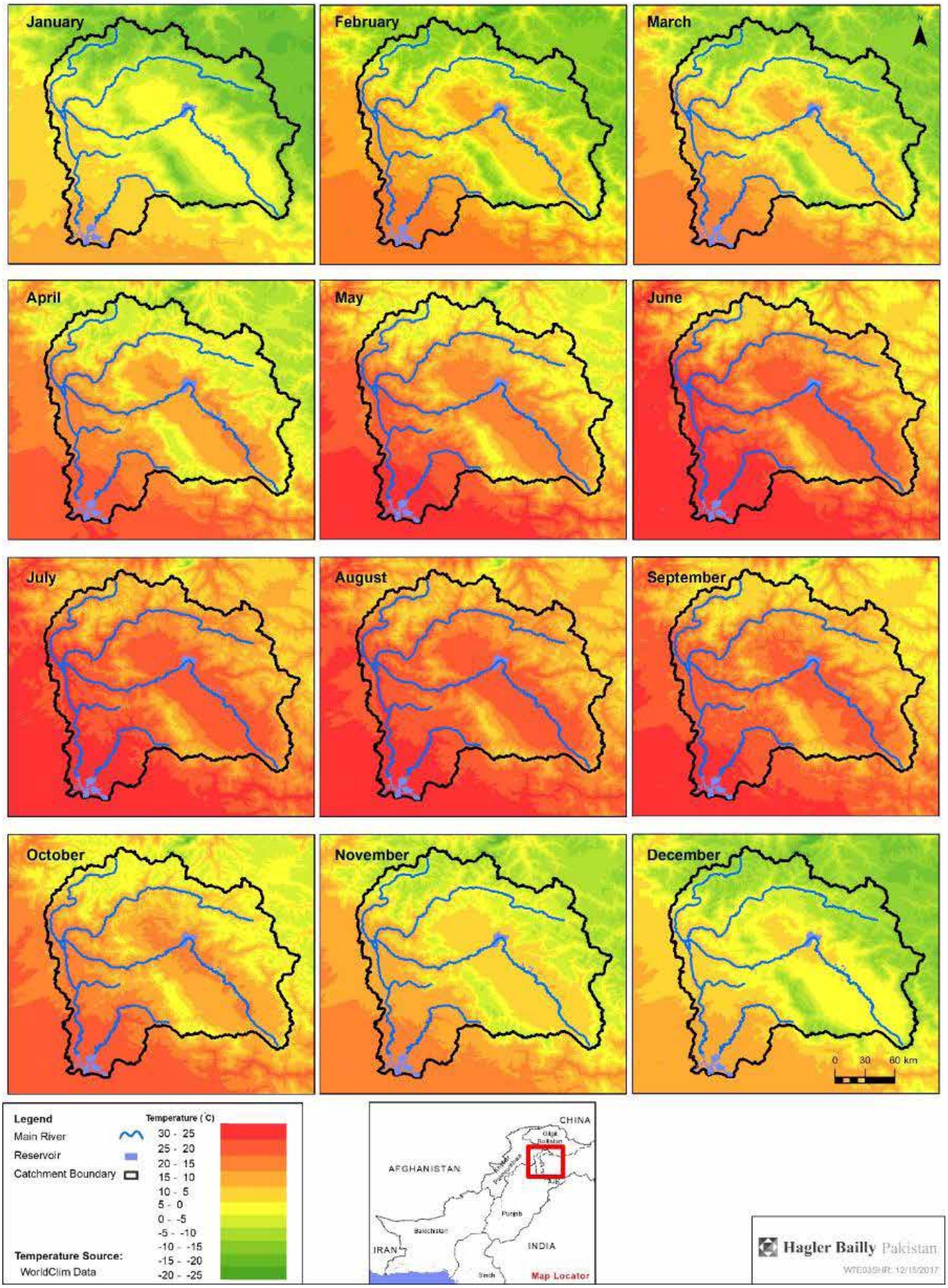


Figure C-6: WorldClim Gridded Precipitation (1970-2000)

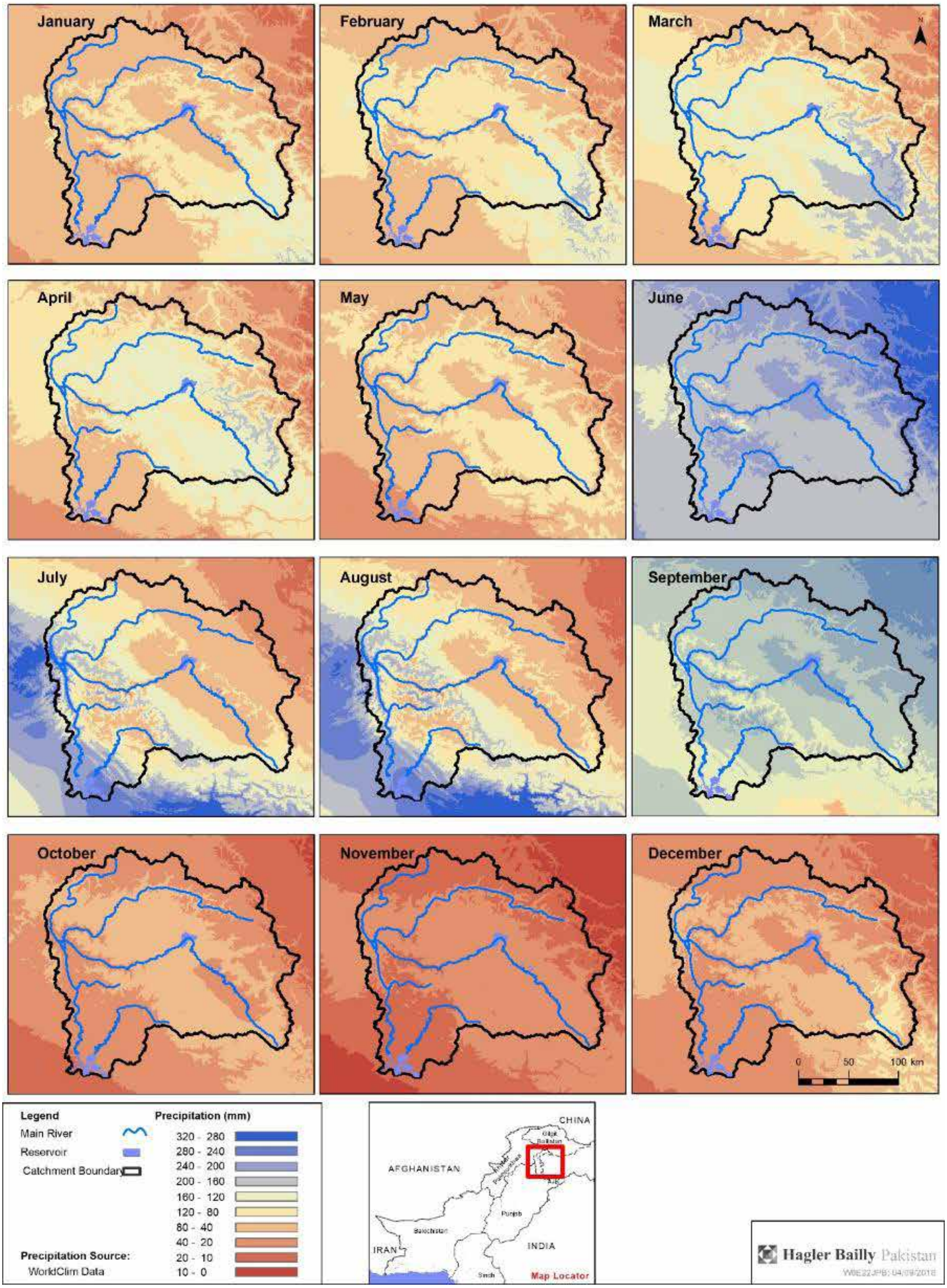


Table C-2: Mean Monthly Temperature (°C) in Jhelum-Poonch Basin

Basin Name	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Neelum Basin	-8	-7	-3	3	9	14	15	15	12	7	1	-5
Kunhar Basin	-6	-6	-2	5	9	14	16	15	13	7	2	-3
Middle Jhelum Basin	1	3	7	12	16	21	21	21	19	13	8	3
Upper Jhelum Basin	-3	-2	2	8	13	17	18	18	16	10	4	-1
Poonch Basin	5	7	11	16	21	24	24	23	21	17	12	8
Lower Jhelum Basin	8	10	14	20	24	28	27	26	24	20	15	10

Figure C-7: Mean Monthly Temperature (°C) in Jhelum-Poonch Basin

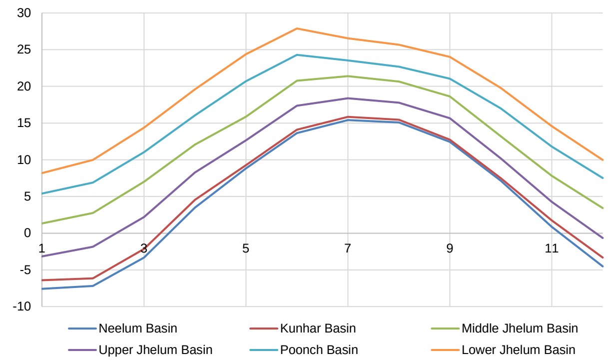
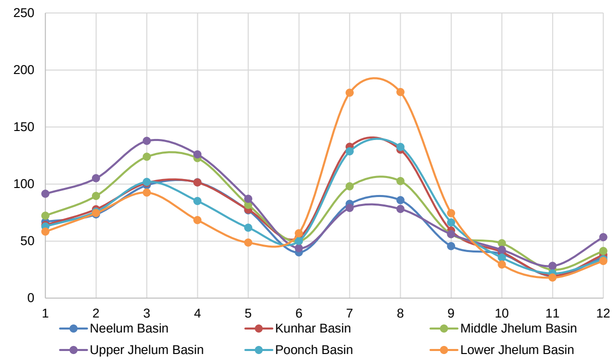


Figure C-8: Mean Monthly Temperature (°C) in Jhelum-Poonch Basin



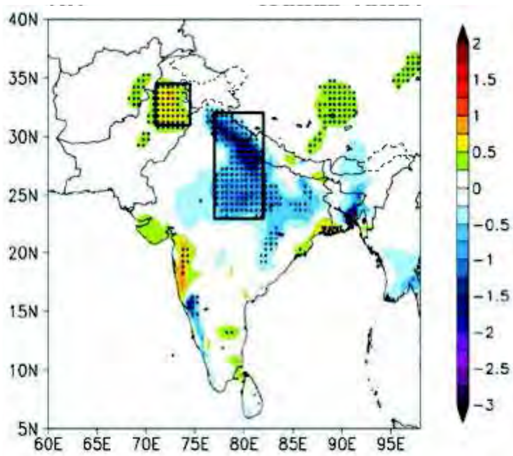
C.3.1.1 Precipitation Trends

Observed trends indicate that the annual, as well as June, July, August and September (JJAS) rainfall over most of India is decreasing.[14,15] However, the trend in the core monsoon region of Pakistan shows increasing JJAS rainfall. The JJAS precipitation increase for the Jhelum-Poonch Basin is between 0.25 mm/yr. and 0.5 mm/yr. (**Figure C-9**).

At regional and continental scales there is low to medium confidence in trends in heavy precipitation in Asia (SREX[16]). There is, however, a likely statistically significant increase in global number of heavy precipitation events, extreme precipitation changes since the 1950s for the SASM. The SREX notes that heavy precipitation increased in India especially during the monsoon seasons[17,18].

These trends indicate a changing climatic regime for the Jhelum-Poonch Basin.

Figure C-9: Trend in SASM Rainfall - JJAS (1951-2011) using CRU dataset (mm/year)



Source: Latif, M., Syed, F., & Hannachi, A. (2016). Rainfall trends in the South Asian summer monsoon and its related large-scale dynamics with focus over Pakistan. Climate Dynamics, 48(12), 3565-3581.

[14] Latif, M., Syed, F., & Hannachi, A. (2016). Rainfall trends in the South Asian summer monsoon and its related large-scale dynamics with focus over Pakistan. *Climate Dynamics*, 48(12), 3565-3581.

[15] Kumar, V., Jain, S. K. & Singh, Y. (2010) Analysis of long-term rainfall trends in India. Hydrol. *Sci. J.* 55(4), 484–496.

[16] IPCC, 2012, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)

[17] Rajeevan, M., Bhate, J., & Jaswal, A. (2008). Analysis of variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data. *Geophysical Research Letters*, 35(18)

[18] Sen Roy, S. (2009). A spatial analysis of extreme hourly precipitation patterns in India. *International Journal of Climatology*, 29(3), 345-355.

C.4
Hydrology

The mean monthly flows within the Upper Jhelum and its tributaries are shown in **Figure C-10**.

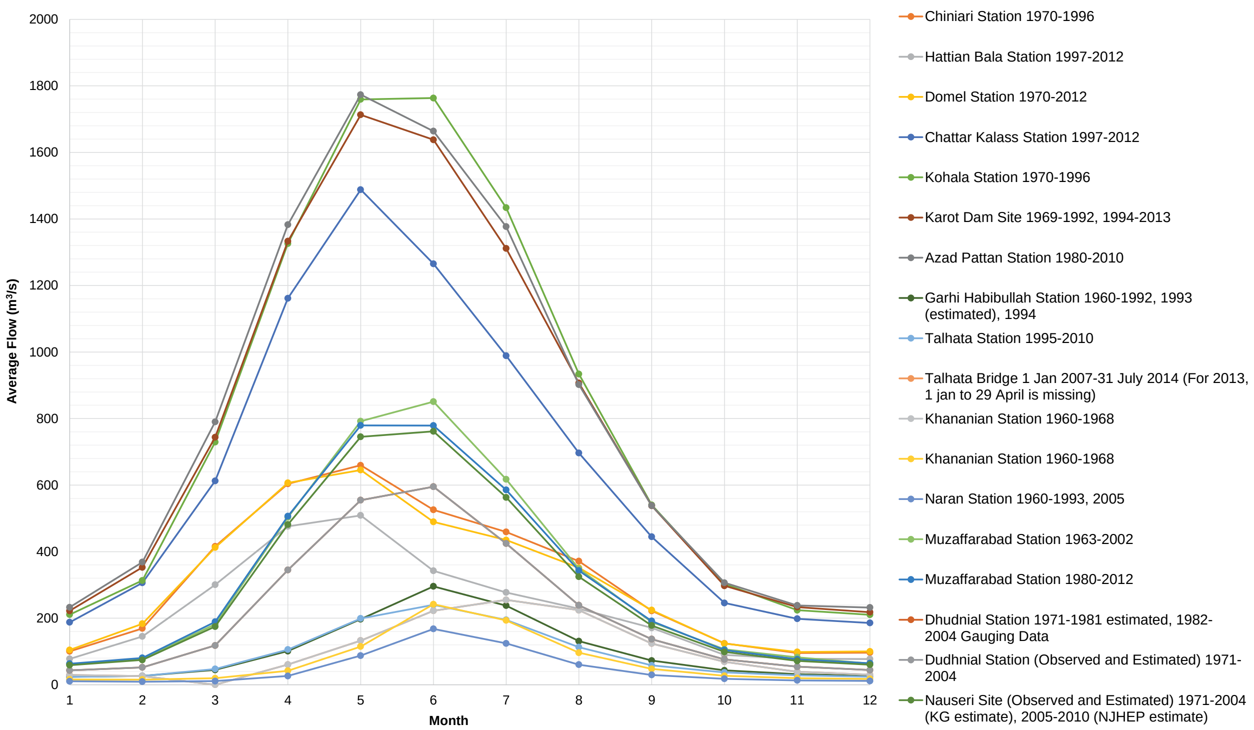
On comparison of the WorldClim precipitation (**Figure C-10**) it is evident that the flows do not completely correspond to the precipitation, particularly for winter. This is because the catchment experiences snowfall, associated with the western disturbances in winter months, which does not immediately report to the River. In spring, as temperatures start to increase, snow begins to melt and the flow starts to increase, compounding the impact of SASM rainfall. There is a positive relationship between flow and summer precipitation (rainfall), and a negative relationship between flow and temperature.

The catchment is not extensively glaciated, as with the Karakoram or the Central Himalaya, therefore glacial melt is not expected to contribute greatly to the flow. However, a larger number of glaciers are present in the Upper Jhelum, Poonch and Naran Basins compared to the Middle and Lower Basin where there are fewer glaciers.

Flows of the Jhelum River, upstream of its confluence with Neelum River (Domel Station), are higher than the Neelum (Muzaffarabad Station) from January to April. However, the flow of Neelum exceeds that of Jhelum from May to August and thereafter flow of both these rivers remains almost equal up to November. The flow in Neelum during summer is higher since the Neelum is fed by snowmelt and rain during summer, compared to the Jhelum River, prior to its confluence with Neelum, which has greater glacial melt from the Higher Himalaya and the Pir Panjal Range. Difference in start of spring melt exist within the basin.

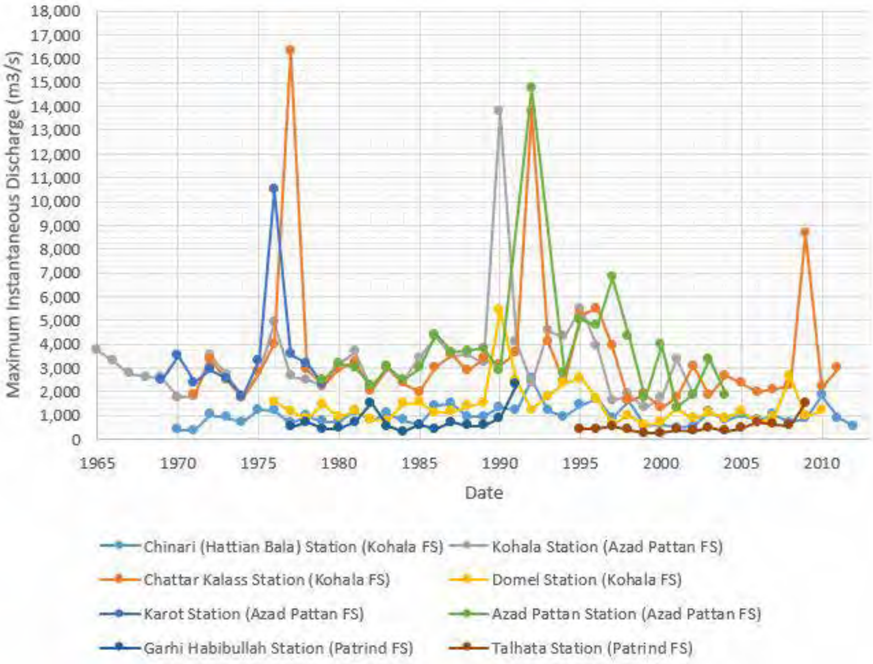
To the south of the catchment (Kohala and Chatter Kalas gauging stations), October to February is the low-flow period, while the flood season is from April to August. March and September are transition phases from the dry to wet, and wet to dry seasons respectively (see **Figure C-11**).

Figure C-10: Average Flow by Month along Jhelum and within Major Tributaries



Note: Compiled using various sources including the ESIA reports listed in ***Section 1.7***, Sources of Information.

Figure C-11: Annual Maximum Instantaneous Discharge



C.5 Land Cover Changes

This section describes the changes in land cover in the Jhelum-Pooch basin between 1993 and 2014. Assessment of land cover provides a comprehensive understanding of the interaction and relationship of anthropogenic activities with the environment[19]. Land cover is dynamic and changes in land cover have an impact on the sediment profile of the basin including the sediment load in the rivers.

C.5.1 Methodology

Data from two Landsat sensors was used to assess changes in land cover in the Jhelum-Poonch Basin, including territories in Pakistan and India. Surface reflectance products of Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Manager (OLI) were downloaded for the month of June 1993 and June 2014 respectively. Both, TM and OLI sense the earth reflected radiations in different ranges of the electromagnetic spectrum and thus are commonly known as multispectral sensors. These datasets are freely available at United States Geological Survey's (USGS's) Earth Explorer website.[20] Earth Resources Data Analysis System (ERDAS) Imagine 2014 was used as a primary image processing software. ArcGIS 10.4 was also utilized on a need basis to process the images. Detailed methodology for land cover mapping used for the Jhelum-Poonch Basin is provided in Annex C.A, *Land Cover Change Analysis*, of **Annex C**.

The following land cover classes or habitat types were identified (**Table C-3**).

Table C-3: Description of Land Cover Classes

No.	Land cover Class	Description
1	Forest and Scrubs	Contains, coniferous and broadleaf forests and scrubs (thick and sparse)
2	Grasses and Sparse Vegetation	Contains grasses, shrubs, herbs and very sparse vegetation
3	Orchards	Contains orchards (fruit trees)
4	Cultivated Cropland	Contains those areas of cropland which were cultivated at the time of imaging
5	Urban Areas	Contains urban areas and large settlements
6	Bare land	Contains bare land (including fallow agriculture land) and bare rocks
7	Waterbody	Contains rivers, lakes and other water reservoirs
8	Snow and Ice	Contains snow, ice and glaciers

19 Kiran, V. S. S. (2013). Change Detection in Land use/Land cover Using Remote Sensing & G. I. S Techniques: A Case Study of Mahananda Catchment, West Bengal. *International Journal of Research in Management Studies*, 2, 68-72.

20 Official Website of United States Geological Survey's (USGS's) Earth Explorer website. Available at https://earthexplorer.usgs.gov.

C.5.2 Results

The Jhelum-Poonch Basin is defined in **Section 1.3** (Area of Management in Strategy for Sustainable Hydropower Development) and includes territories both in India and Pakistan. The land cover maps (**Figure C-12**) for the Jhelum-Poonch Basin for 1993 and 2014 were assessed and statistically analyzed for changes at the basin level (**Figure C-13**) and sub-basin level (**Figure C-14**). The key findings are summarized below:

- Overall, Forests and Scrubs were the most dominating land cover feature in 1993, but in 2014, Bare Land became the most dominating feature. Forests and Scrubs have decreased by 6.6 percent whereas Bare Land has increased by 8.6 percent during this period. The same trend can be observed in all sub-basins of Jhelum-Poonch Basin in India and Pakistan, including the Area of Management. It indicates that deforestation and cutting of scrubs is increasing with time.
- The Upper Jhelum Basin which is administered by India, is the most active region in terms of change in land cover. There has been a decrease in Forests and Scrubs and Cultivated Cropland and an increase in Orchards, Bare Land, and Urban Area (**Figure C-14**).
- Overall, there has been a small reduction in grasses except for the Lower Jhelum Basin (in Pakistan) and Middle Jhelum Basin.
- The area of large Water Bodies observed is almost the same in 1993 and 2014
- Urban Area has increased in the sub-basins in India. An example is Srinagar city which is surrounded by agriculture land, and any expansion of the city is directly correlated with a reduction in cultivated or fallow land.
- There has been a decrease in Cultivated Cropland particularly for basins located in India. The Upper Jhelum Basin (India) experienced the maximum reduction in Cultivated Cropland.
- There has been a small increase in the area of Orchards

The changes in land cover classes are interlinked. For example, reduction in Forest and Scrubs area signifies deforestation and a corresponding increase in Barren Land. However, fallow land, left uncultivated in a particular season will be detected as Bare Land in the satellite image. A fallow land may become cultivated, and cultivated land may be left fallow. Therefore, a decrease in Irrigated Cropland observed in 2014 does not necessarily mean a decrease in agriculture activity. It is just the land cover feature/habitat observed in that month (June 2014). To construct a more concrete statement regarding agricultural activities it is necessary to monitor monthly or seasonal cultivation patterns in the basin for an entire year.

The habitat Grasses and Sparse Vegetation is highly dependent on rainfall and thus Grasses and Bare Land are inter-changeable from year to year depending on the rainfall.

Figure C-12: Land Cover Map for Jhelum-Poonch Basin

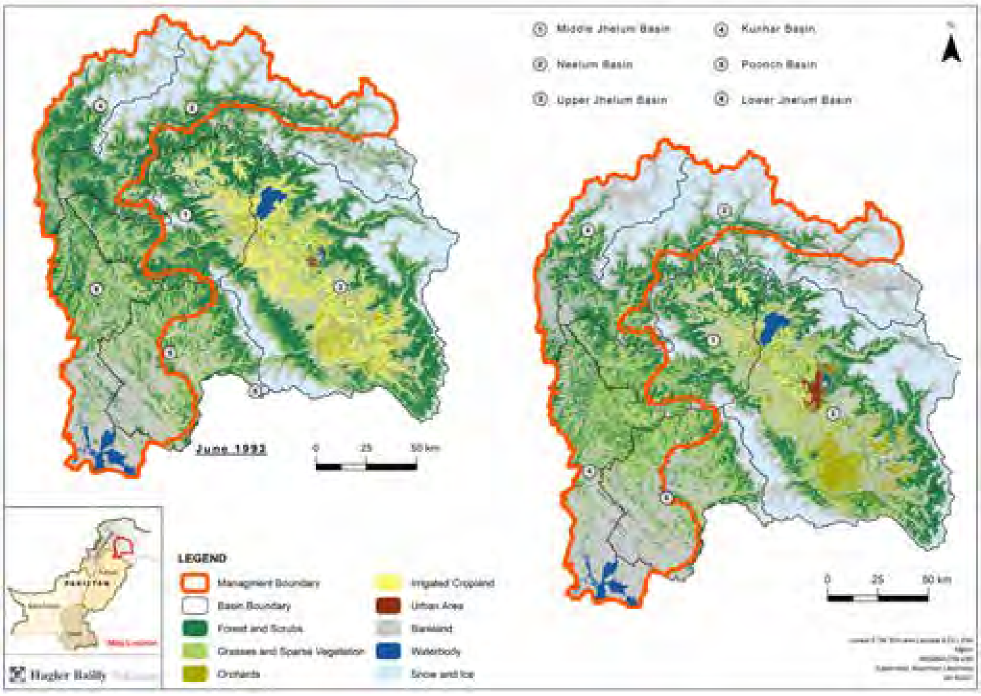


Figure C-13: Statistics for Land cover in Jhelum-Poonch Basin

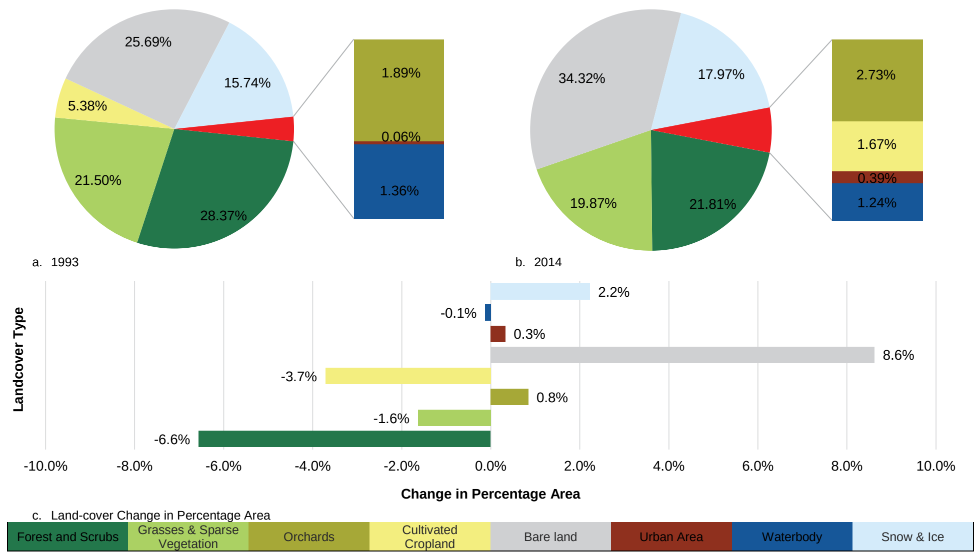


Figure C-14: Percentage Change in Land Cover in Sub-Basins between 1993 and 2014

Basin Name	Basin Area (Km²)	Percent Change in Landcover Type (as per sub-basin area)							
		Forest and Scrubs	Grasses and Sparse Vegetation	Orchards	Irrigated Cropland	Urban Area	Bare Land	Waterbody	Snow and Ice
Lower Jehlum	3,605	-4.2%	1.2%				4.1%	-1.1%	
Middle Jehlum	4,187	-7.9%	5.4%	-0.4%	-4.0%		5.3%		1.6%
Upper Jehlum	10,208	-3.7%	-0.6%	2.8%	-10.1%	1.1%	8.0%	-0.1%	2.6%
Neelum	7,416	-9.4%	-6.4%				11.8%		4.0%
Kunhar	2,633	-11.0%	-8.2%				15.9%	0.1%	3.3%
Poonch	4,206	-6.6%	-1.0%		-0.1%		7.1%		0.6%

Note: Green indicates increase in area of the habitat; red indicates decrease in area of habitat; empty cell shows that habitat is not present in that basin.

C.6 Sediment Audit

The sediment profile of the rivers in the Area of Management was evaluated by conducting a sediment audit which assessed existing sediment data for the Jhelum Rivers in combination with available information on basin geology, to predict how sediment loads and patterns are expected to change with HPP development in the basin. Details are available in Annex G.A, *Sediment Audit* and *Drift DSS*, of **Annex G.**

Sediment monitoring data is available for most rivers in the basin and the assessments in the sediment audit used this data, in combination with sediment yield data provided in the various Environmental Impact Assessment Reports for hydropower projects in the region. These include Kishanganga (in India-administered Kashmir) and Neelum-Jhelum HPP on Neelum River, Patrind and Balakot HPP on Kunhar River as well as Kohala, Karot, Mahl and Azad Pattan HPP on Jhelum River. There are additional HPPs in the catchments, such as the Parnai, Uri 1 and Uri 2 projects but they are not included in this review as they are located in India and not in the Area of Management.

C.6.1 Objectives of the Sediment Audit

The sediment audit is based on the principles of Temane *et al.* (2014)[21], who showed that expert knowledge and rapid characterization of catchments, in terms of susceptibility to erosion, are viable options for assessing siltation risks and for analyzing controlling factors at a larger number of dams.

In accordance with this approach, the sub-tasks addressed in this report are to collate and evaluate existing data on sediments for the Neelum-Jhelum Rivers and use this, in combination with available information on basin geology, to predict how sediment loads and patterns could be expected to change with HPP development in the basin. The approach considers sediment as three components: bedload, sand, and silt plus clay to account for their different transport mechanisms and susceptibility to change due to hydropower development. Due to the availability of sediment monitoring results for all waterways, this assessment has relied more on data than on high level basin characteristics.

C.6.2 Catchment Attributes

The Neelum-Jhelum and Poonch Rivers drain the foothills of the Himalayas, and encompass elevations extending from ~380 m at the confluence with the Mangla Reservoir to over 5000 m, snow-capped peaks. In the Neelum, Kunhar and middle Jhelum sub-basins, these valleys are narrow and surrounded by very steep mountainous areas. Although lower in elevation, the rivers have steep slopes. The Neelum River slope increases with distance downstream of the Kishanganga HPP, and is steeper than the middle Jhelum River. From the Kishanganga HPP site, the river drops approximately 1,700 m over a distance of ~200 km. The slope of the lower Jhelum River reduces downstream of the confluence. The Kunhar River is the steepest of the upper rivers, losing 2,000 m in elevation over ~130 km. The long-section for the Poonch River only extends to the Line of Control (LoC) between Pakistan- and Indian-administered Kashmir and shows a concave river profile similar to the other rivers. Elevation bands for the Poonch River, which include the entire basin, show a decrease in area with decreasing elevation, consistent with the broadening of the catchment with distance from the headwaters, with about 60% of the catchment above 1,500 m elevation.

Geologically, the area is tectonically active and complex, and experiences high rates of seismicity.[22] A number of the geologic units are present in the Neelum River, and show that numerous units are present over relatively short distances reflecting the intense folding and faulting of the area. The presence of different lithologies on opposite banks of the river suggests the river may be occupying a fault zone. Quartz is abundant in several of the geologic units common throughout the Jhelum-Poonch Basin and this resistant mineral is present in high quantities in the sand load of the river, making management of sand an important issue for turbine maintenance as well as reservoir capacity. Other minerals, such as micas or carbonates, are relatively soft and quickly abrade to silt or clay sized material, contributing to the large silt load of the rivers, or dissolve completely.

C.6.3 Geomorphic Processes Affecting Sediment Transport

Many factors affect sediment transport and geomorphology in a river catchment. At the largest scale, the region is experiencing rapid tectonic uplift, which is a major determinant in erosion, as mountains typically erode at a rate similar to uplift.[23] The strong tectonic forces can shear and weaken rock units, making them more susceptible to weathering and physical erosion.[24] Tributaries are the main source of sediments to the mainstem rivers with sheetwash and gully erosion associated with high rainfall, and mass-wasting events such as landslips and avalanches identified as important processes.[25] The tributaries and valley walls of the main rivers are exceedingly steep, and can rapidly deliver the large volumes of sediment generated by these processes to the main valleys. The sediment grain sizes generated by these processes range in size from boulders in excess of 1 m to clay size. Additional activities that can contribute to sediment loads in rivers include road construction,

[21] Temane, L., Le, Q.B. and Vlek, P.L.G. 2014. A landscape planning and management tool for land and water resources management: An example application in northern Ethiopia. *Water Resources Management* 28(2): 407-424.

[22] NORSAR and Pakistan Meteorological Department, 2006, *Seismic Hazard Analysis for the cities of Islamabad and Rawalpindi*.

[23] Milliman, J.D. and Syvitski, J.P.M., 1992, Geomorphic/Tectonic Control of Sediment Discharge to the Ocean: The Importance of Small Mountainous Rivers, *Journal of Geology*, 1992, vol. 100, pp. 525-544

[24] Hren, M.T., Hilley, G.E., and Chamberlain, C.P., 2007, The relationship between tectonic uplift and chemical weathering rates in the Washington Cascades: Field measurements and model predictions *Journal of Science* Online November 2007 vol. 307 no. 9 1041-1063

[25] Norconsult and Norplan. 1997. *Neelum-Jhelum Hydroelectric Project*, prepared for Pakistan Water and Power Development Authority.

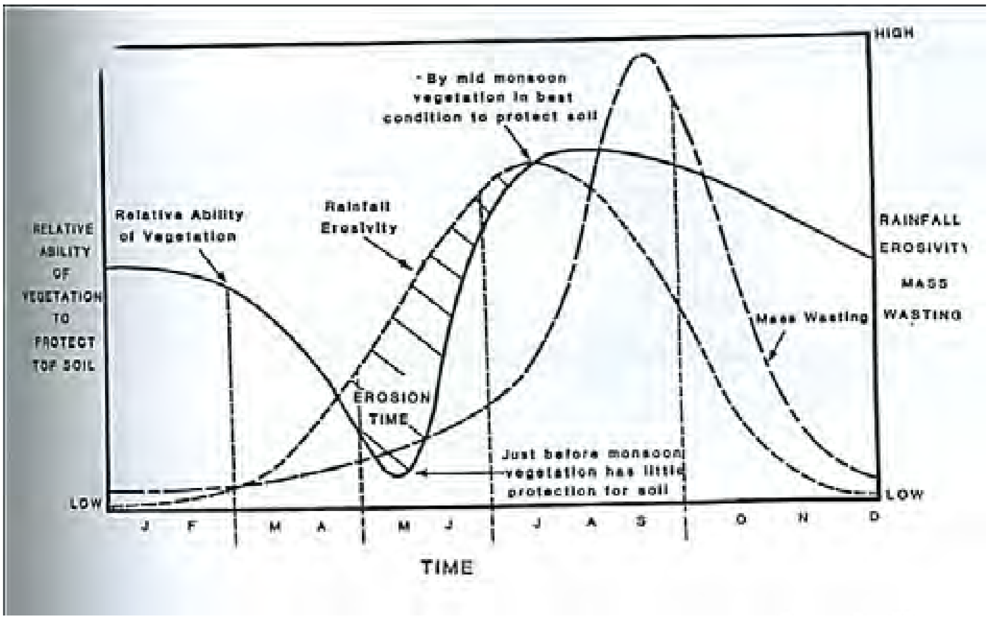
livestock grazing, agriculture, and deforestation. Due to the steep nature of the main rivers in the Jhelum-Poonch Basins and the high rainfall, the rivers have sufficient energy to transport the material being 'shed' by the rapidly uplifting mountainous terrain resulting in deeply incised and steep valleys with limited accumulation of alluvial deposits in most areas.[26]

The relative importance of different erosional processes compared to the stability provided by vegetation and rainfall patterns over a year in the Himalaya is shown in **Figure C-15**. The onset of the wet season is a time of high erosion risk owing to low stability provided by vegetation after the extended dry winter season. During this period, large volumes of sediment are delivered to the rivers ('erosion time' in **Figure C-15**). As the monsoon progresses, vegetation recovers and increases slope stability, thus reducing the erosive impact of rainfall. At the end of the monsoon, as hillslopes become saturated, the risk of mass wasting (land slips, avalanches, river bank collapse) increases, providing episodic sediment input to rivers. In addition to the processes depicted in **Figure C-15**, snowmelt and glacial erosion are also important sediment input processes in the Neelum-Jhelum Rivers.

The complexity of erosion and stability processes in the steep and tectonically active landscape results in river systems where sediment transport is determined more by sediment delivery to the rivers rather than by the transport capacity of the rivers (e.g. discharge). This facet of the landscape results in the following characteristics:

- Sediment transport is highly variable over both short and long-time frames.
- The high variability of sediment delivery to the rivers makes quantifying sediment transport difficult, as even daily measurements are unlikely to capture all variability.
- The high turbulence and velocity of the rivers combined with shifting channels makes the collection of accurate flow measurements difficult.
- There is a poor correlation between river flow and sediment transport. This is because sediment transport is governed more by the delivery of sediment to the rivers than by the transport capacity of the rivers, e.g., the rivers typically have the energy to transport all sediment delivered to the valley floor, so sediment supply is the limiting factor rather than river flow (e.g. energy).
- Sediment delivery and transport is affected by episodic events such as glacier lake outburst floods, landslips and avalanches with the capacity to block the river, or other large mass wasting events that can deliver far greater than the 'average' sediment load to the river in a short time.

Figure C-15: Interaction Stability provided by Vegetation and Erosional Processes Over One Year[27]



[26] Norconsult and Norplan. 1997. *Neelum-Jhelum Hydroelectric Project*. Prepared for Pakistan Water and Power Development Authority.

[27] Ibid.

C.6.4 Sediment Transport Characteristics

Sediment loads

The suspended sediment data used in the feasibility studies are summarized in **Table C-4**. The 'periodicity of data' indicates the time-step at which the results are presented, and not the monitoring frequency, e.g., the daily data is not available on a daily basis for the period of record, but rather some daily measurements are available for the period. The station with the longest record is Kotli in the Poonch River. In the Jhelum, the Patrind HPP site has the longest record, but no results are available for the past 15 years, such that recent changes associated with land use or hydropower development are not captured in the available monitoring results. Sediment transport monitoring in the Jhelum and Poonch Basins has been limited to the collection of suspended sediment, with no bedload measurements collected at any site.

A summary of catchment, flow and sediment transport information derived from the feasibility studies for each existing or potential HPP site included in the analysis is provided in **Table C-5**. Where possible, ranges of suspended sediment transport loads are included. Bedload transport was estimated in the various ESIAs by assuming a fixed percentage of the suspended sediment load. These estimates ranged from 10% to 30% (**Table C-5**).

The results of the ESIAs were used to derive sediment yields (tonnes of sediment/km²/yr.) for the sites. These yields are average values, and sediment input can vary markedly over short distances. An example is provided in the upper Kunhar River where sediment yields varied more than 10-fold between Naran, a site located near the headwaters, and sites monitored lower in the catchment. Based on the derived sediment yields, the middle Jhelum River has a very low sediment yield, largely attributable to the trapping of sediment in Wular Lake and the Uri power developments, located in the basin upstream of the LOC. The sediment volumes estimated for the Kohala Dam site reflect sediment input from downstream of the lake, which is a much smaller catchment area. The Kunhar River at Balakot and Patrind HPPs has similar yield values, while the Neelum River at the Neelum-Jhelum HPP head-pond shows the highest sediment yields. The sediment yields in the Lower Jhelum are intermediate between these values.

The reported results were used to construct a sediment budget for the Mangla Reservoir, showing the sediment derived from each sub-catchment upstream of the confluence at Muzaffarabad, the Lower Jhelum, and Poonch River. Both suspended and bedload sediments are included. The balance suggests that the Neelum River is the largest single source of sediment in the Neelum-Jhelum Basin, contributing almost half of the sediments to the lower Jhelum River and more than a third of the sediment reporting to Mangla Reservoir. The middle Jhelum and Kunhar Rivers contribute 10% and 14% of the load in the lower Jhelum River, respectively, resulting in about 70% of the Jhelum sediment load being derived from the middle Jhelum, Neelum and Kunhar Rivers. Inputs in the Lower Jhelum appear to be evenly distributed between the area draining to the Mahl and Azad Pattan HPP sites. No change in sediment load is recorded between the Azad Pattan and Karot sites. The Poonch River is estimated to contribute ~12 Mt/yr, or 24% of the load entering the Mangla Reservoir.

The total calculated sediment load entering the Mangla Reservoir is 50.1 Mt/yr. This value is similar to the average rate of annual deposition within the reservoir of 52 Mt/yr based on hydrographic surveys conducted at 3 to 5-year intervals of the impoundment.[28] The Mangla Reservoir is a large and broad water body, and sediment trapping is considered to be >90% and close to 100%.[29] The range of sediment deposition in the impoundment (25 – 94 Mt/yr) shows variability, consistent with the variable nature of sediment delivery from the catchments.

The sediment budget is shown in **Table C-6** and presented graphically in **Figure C-16**. The average values result in a very good sediment balance and provide a framework for quantifying future changes. However, 'average' years rarely occur, and understanding the variability of sediment transport and the characteristics of the sediments are necessary to predict how sediment loads will change in the future under hydropower scenarios.

[28] Pakistan Engineering Services, Ltd, Fichtner GmbH & Co., and K.G. Stuttgart Germany. 2007, *Patrind Hydropower Project Feasibility Study*

[29] Ibid

Table C-4: Summary of Sediment Transport Data Available in Feasibility Studies

Stations with Sediment Data Available from Current Feasibility Studies	Periodicity of data	Period of Data
Kohala dam site - Upper Jhelum	Yearly	1965-2004
Azad Pattan – Lower Jhelum	Monthly	1979-2004
Gari Habibullah-Kuhnar River	Daily	1975-1994
Talhatta - Kunhar	Daily	1995-1996
Paras Bridge-Kunhar	Daily	2012-2013
Kotli - Poonch	Daily	1965-2011
Patrind - Kunhar	Daily	1960-2002

Table C-5: Summary of Catchment Areas, Flow Rates and Sediment Transport Rates for HPP Projects

River/ Site	Catchment Area Km^2	Average Annual Discharge[30] and Volume (Mm^3)	Annual Suspended Sediment Mt/yr.	Annual Bedload Sediment Mt/yr. (%SS Load)	Sediment Yield Tons/square km[31]
Neelum/ Kishanganga HPP	1,815	104 m^3/s 3,280 Mm^3	1.23 Mt/yr[32]		375 t/km^2
Neelum/ Neelum-Jhelum HPP	7,278	365 m^3/s 9,000 Mm^3 (Nauseri)	11.5 Mt/yr (up to 19.7 observed)	3.4 Mt/yr (30%)	2,245 t/km^2
Upper Jhelum/ Kohala HPP	14,060	302 m^3/s 9,520 Mm^3	3.17 Mt/yr (0.7 – 9.2)	0.47 Mt/yr (15%)	225 t/km^2 (based on total upstream catchment area)
Muzaffarabad/ Neelum R	7,278	336 m^3/s 10,600 Mm^3	16.3 Mt/yr Based on yield		2,245 t/km^2
Kunhar/ Balakot HPP	1,951	91.8 m^3/s 2,895 Mm^3	2.36 Mt/yr (0.33 – 11.7 Mt/yr)	0.35 Mt/yr (15%)	1,855 t/km^2
Kunhar/ Patrind HPP	2,429		4.72 Mt/yr		1,900 t/km^2
Domel/ Jhelum	14,505	321 m^3/s 10,123 Mm^3	3.44 Mt/yr		
Lower Jhelum at Kohala discharge		780 m^3/s 24,598 Mm^3	(19.78) Mt/yr (Mahl ESIA)[33]		
Lower Jhelum / Mahl HPP	25,334	796 m^3/s 25,102 Mm^3	30.3 Mt/yr (3.6 – 77.8)	4.54 Mt/yr (15%)	1,195 t/km^2
Lower Jhelum/ Azad Pattan HPP	26,500	811 m^3/s 25,576 Mm^3	35.87 Mt/yr (10-86.7 Mt/yr)	5.4 Mt/yr (15%)	1,386 t/km^2
Lower Jhelum / Karot HPP	26,700	819 m^3/s	33.15 Mt/yr	4.97 Mt/yr (15%)	1,242 t/km^2
Poonch R	~3,800 to project site	126 m^3/s	10.8 Mt/yr[34]	1.1 Mt/yr (10%)	3,315 t/km^2
Mangla Reservoir	33,340	905[35] m^3/s	52 Mt/yr[36]		1,600 t/km^2

Note: Muzaffarabad and Domel are included to provide information about total inputs from Neelum and Jhelum Rivers, respectively.

30 From Mahl ESIA 2018a
31 Estimated
32 Derived from sediment modelling
33 Measurements considered unreliable
34 From HBP 2014
35 From Jhelum only.
36 Reported as 58 Million short-tons.

Table C-6: Sediment Budget in the Jhelum River Basins

River	Suspended Sediment Input Mt/yr	Bedload Input Mt/yr	Total Input Mt/yr	Percent of Jhelum (Based on 40 Mt/yr)	Percent of Total Entering Mangla
Upper Jhelum at Domel	3.4	0.51	3.92	9.8	7.8
Neelum at Muzaffarabad	16.3	2.45	18.75	46.9	37.4
Kunhar at Patrind	4.7	0.71	5.53	13.8	11.0
Total to Lower Jhelum	24.4	3.67	28.2	70.5	56.3
Lower Jhelum at Mahl	30.3	4.5	34.8	87.3	69.5
Lower Jhelum at Azad Pattan	35.9	5.4	41.3	100	82.4
Lower Jhelum at Karot-entering Mangla from Jhelum	33.2	5.0	38.2	100	76.1
Entering Mangla from Poonch	10.8	1.1	11.9		23.8
Total entering Mangla	44.0	6.1	50.1		100.2
Total estimated entering Mangla based on infilling			52.0		

Note: Information based on average annual sediment loads reported in ESIA documents compared to long-term infilling rates of Mangla Reservoir.

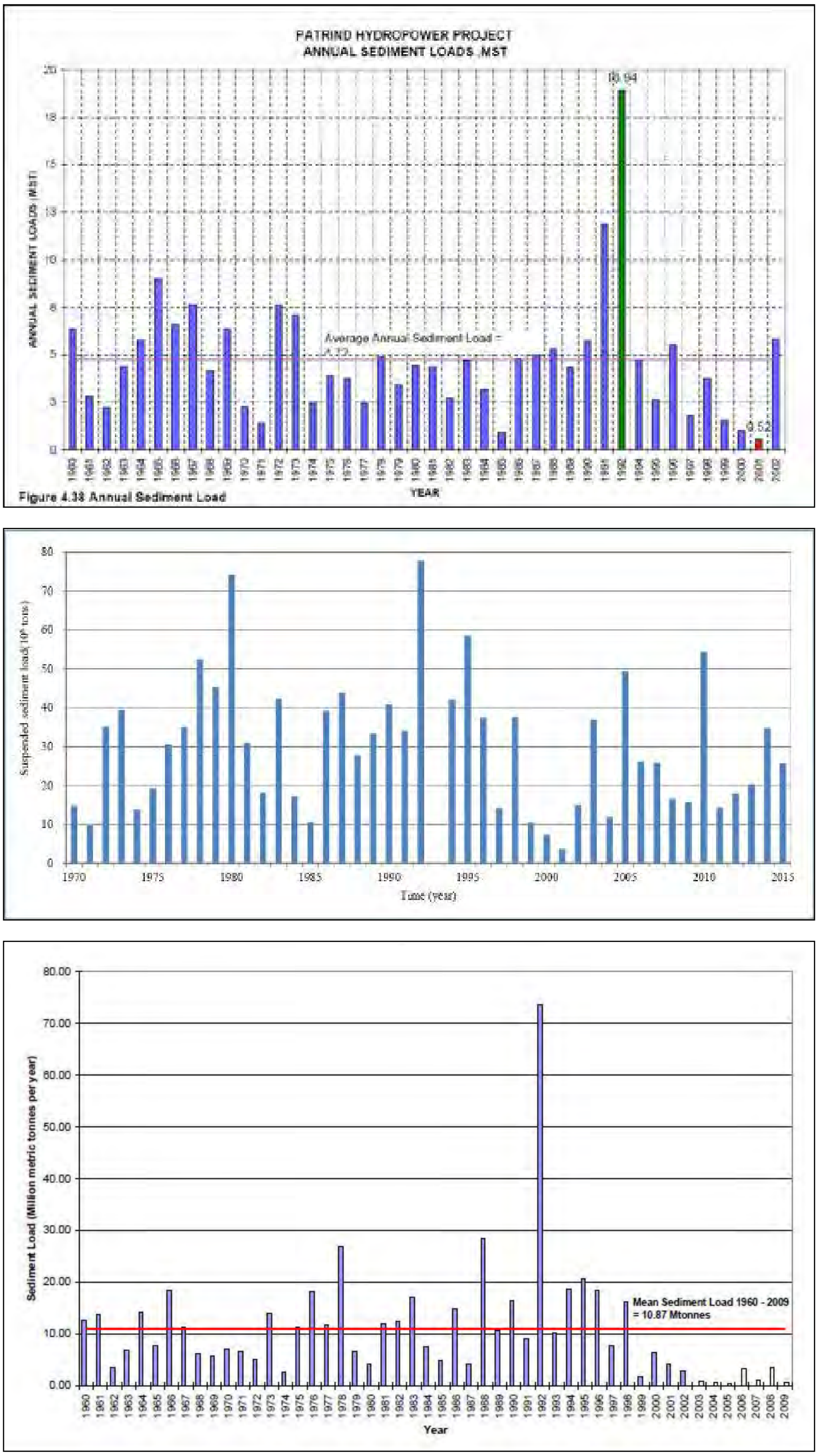
Figure C-16: Sediment Inputs by Tributary or HPP Location based on Sediment Budget

Sediment transport variability

The variability of sediment transport on an annual basis is demonstrated by the results available for the Patrind HPP site (Kunhar R), Mahl HPP site (Lower Jhelum R) and Poonch River (**Figure C-17**). All of the sites show very high variability, with few years having average results. At Patrind, maximum annual loads are ~4-fold higher than the average value, at Mahl, the highest value is slightly higher than twice the average value, with the reduction in variability reflecting the integrating effect of a location lower in the catchment. In the Poonch River, the variability is highest, with maximum loads exceeding the annual average by greater than 7-fold.

Similar variability is observed at the monthly and daily scales. The average monthly values for the same sites are shown in **Figure C-18.** The data from the two sites in the Jhelum River show well defined seasonal patterns, with maximum transport occurring in May to July. The Poonch River data indicates maximum sediment transport in July and August with a smaller peak in March.

Figure C-17: Annual Suspended Sediment Loads at the Patrind HPP site, Mahl HPP Site and Poonch River[37]



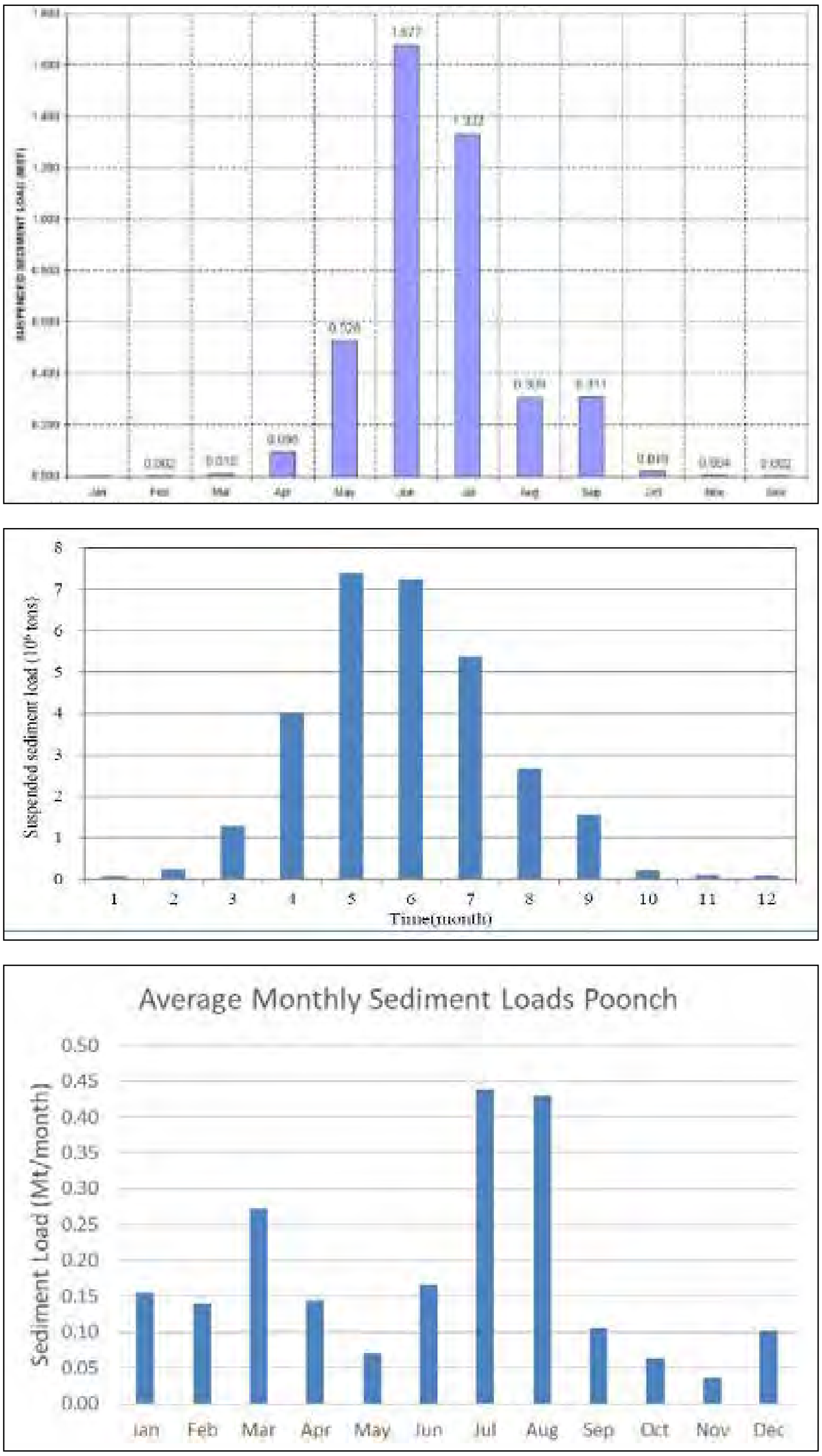
Note: Average values indicated by lines in graphs.

[37] Pakistan Engineering Services, Ltd, Fichtner GmbH & Co., and K.G. Stuttgart Germany. 2007, *Patrind Hydropower Project Feasibility Study*

Mott MacDonald. 2011. *Gulpur Hydroelectric Power Project: Review of Requirement for Desanding Bay* (Final Report). Sambu Construction Co. Ltd, November 2011.

Shanghai Investigation, Design & Research Institute Co. Ltd. (SIDRI) in association with Associate Consulting Engineers (ACE) and Mirza Associates Engineering Services (MAES), January 2017, *Mahl Hydropower Project Feasibility Report, Volume I Main Report* for the China Three Gorges International Corporation (CTGI)

Figure C-18: Average Monthly Sediment Loads for the Patrind HPP Site, Mahl HPP Site and Poonch River



Note: Sources are as in previous Figure except for Poonch River, which was derived by aggregating the available daily data.

Sediment grain-size distribution

The grain-size of sediment largely determines how it will be affected by hydropower developments, and how it will affect the hydropower infrastructure. This analysis of grain-size aims to provide guidance regarding how the sediment loads at each of the HPPs included in this investigation are likely to change.

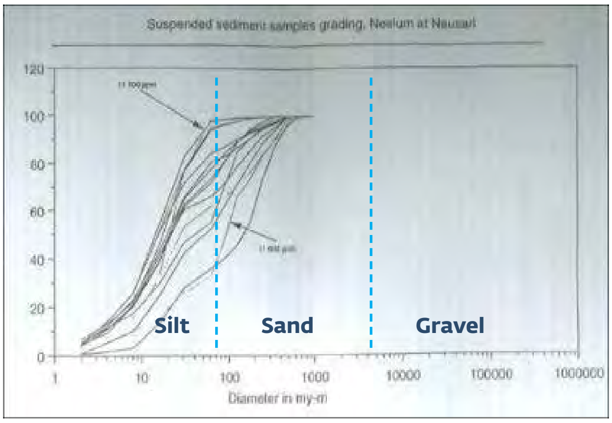
In HPPs with small impoundments, most silt and clay can be maintained in suspension and passed through the impoundment via the power house or direct release of water. Fine-sand (and coarse silt) can be maintained in suspension if water velocities are sufficient, but are likely to accumulate within impoundments during periods of low flows. These size-fractions can frequently be re-mobilized during periods of higher flow and moved through the system. Gravels and larger sized material are very effectively trapped, due to the high velocity required for transport, and the large reduction in velocity that corresponds with the upstream environment of most HPP impoundments. Medium and coarse sand tends to be trapped in impoundments, along with gravels, however, sand is more readily resuspended by sluicing or flushing actions as compared to gravels for which transport is typically limited to bedload. Gravel initially accumulate at the upstream end of the impoundment, creating a delta that infills the valley. This delta 'grows' (progrades) in a downstream direction towards the dam wall as bedload is transported over the surface of the delta and deposited at the delta front. The rate of movement of the delta towards the dam can be increased by flushing, which will move bedload downstream. Once the delta front reaches the toe of the dam material can be 'flushed' through low level gates as bedload. The time required for this to occur will depend on the rate of bedload input to the impoundment, the length and morphology of the impoundment and the frequency of flushing.

The grain-size distribution of suspended and bedload samples collected as part of the ESIA investigations for several of the HPP projects are shown in **Figure C-19**. The results are presented on varying scales and axes, but the delineation between sand and silt is indicated on each figure (~0.06 mm or 6µm). The samples show large variability, but there are some common characteristics:

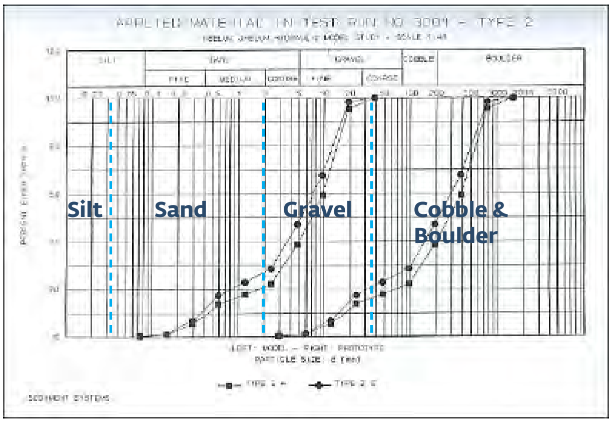
- Suspended sediment contains abundant silt and clay (<63µm).
- The median grain-size of suspended material varies considerably between sites. For example, at Neelum-Jhelum median values (50%) range from ~15 µm (fine silt) to ~200 µm (fine sand), where as in the Kunhar River at Balakot HPP, median grain size is ~300 µm (medium sand).
- Sand generally contributes <50% of the sediment load.
- Bedload material can range from sand sized up to >1-m size boulders.

The bedload results from Patrind Hydropower Project (HPP) show low levels of gravel, with sand and cobbles being the dominant fractions. This distribution is consistent with the armoring of the bed. Armoring occurs when rivers have sufficient energy to transport sand and gravels, but not cobbles or boulders, resulting in a layer of exposed cobbles and boulders on the river bed. These large sized rocks typically overlie finer material (sands and gravels) that are protected from the river flow. During the dry season, finer sediment may also be temporarily deposited on the river bed, enhancing the bi-modal grain-size distribution of bed material. Armoring was highlighted as a potential issue in the head pond of the Neelum-Jhelum[38] with the concern being that the flushing flow would be insufficient to transport cobbles and boulders, and thus unable to access or transport material trapped within or upstream of the armored areas.

Figure C-19: Grain-size Distribution of Suspended and Bedload Sediment from the Neelum, Kunhar and Jhelum Rivers



Neelum-Jhelum: Suspended sediment at Nausari dam site in Neelum River showing wide range of grain-size compositions (Norconsult and Norplan 1997)[39]

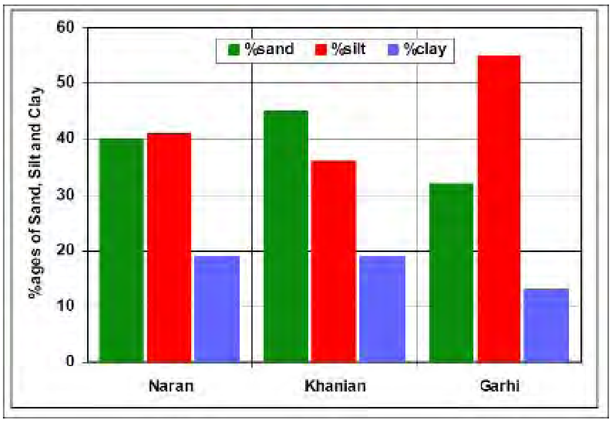


Neelum-Jhelum: Material deposited in head pond under different flow tests (Norconsult and Norplan 1997)[40]

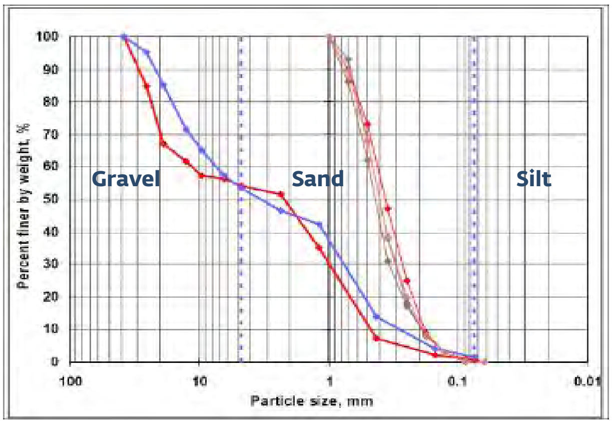
[38] Norconsult and Norplan. 1997. *Neelum-Jhelum Hydroelectric Project*, prepared for Pakistan Water and Power Development Authority.

[39] Ibid.

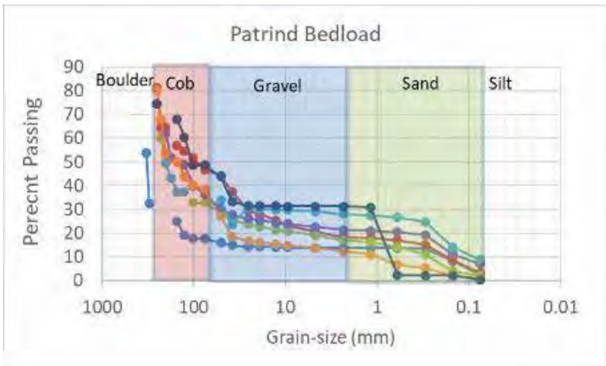
[40] Ibid.



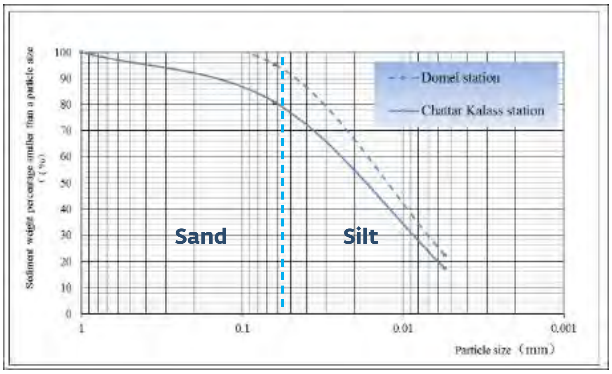
Grain-size distribution of suspended sediment at Kunhar gauging sites, locations shown (Mirza 2013)[41]



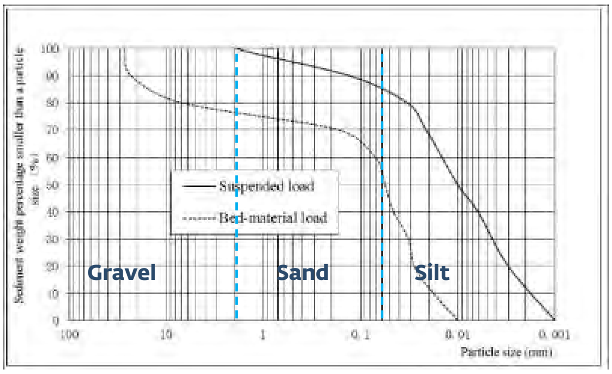
Grain-size distribution curves at the Balakot dam site in the Kunhar River. The left two lines show results for bedload, the other three lines are suspended sediment (Mirza 2013)[42]



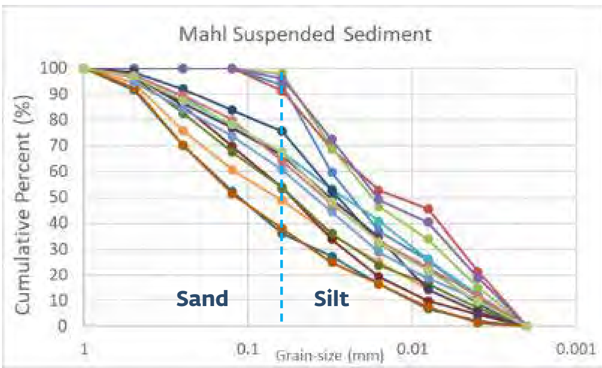
Grain-size distribution of bedload in Kunhar River at – Patrind dam site. Each line shows the results of one sample. Data from Pakistan Engineering Services, et al. 2007[43]



Grain-size distribution results from gauging sites in the Middle Jhelum (HBP 2016)[44]



Bed load and suspended sediment grain-size distribution results from the Kohala Dam site (HBP 2016)[45]



Lower Jhelum at Mahl dam site (data from Mahl ESIA)[46]

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[41] Mirza Associates Engineering Services (Pvt.) Ltd. (Lead Consultant), December 2013, *Feasibility Study of Balakot Hydropower Project* (BPK), Asian Development Bank (ADB).

[42] Ibid.

[43] Pakistan Engineering Services, Ltd, Fichtner GmbH & Co., and K.G. Stuttgart Germany. 2007, *Patrind Hydropower Project Feasibility Study*

[44] Hagler Bailly Pakistan (HBP) and Southern Waters. 2015b. . *Environmental Flow Assessment for Kohala Hydroelectric Project*

[45] Ibid.

[46] Hagler Bailly Pakistan, March 2018a, *Environment and Social Impact Assessment of Mahl Hydropower Project* for Shanghai Investigation Design & Research Institute Co. Ltd., Islamabad

Figure C-20: Grain-size Distribution at Proposed Mahl HPP Applied to the Monthly Sediment Load

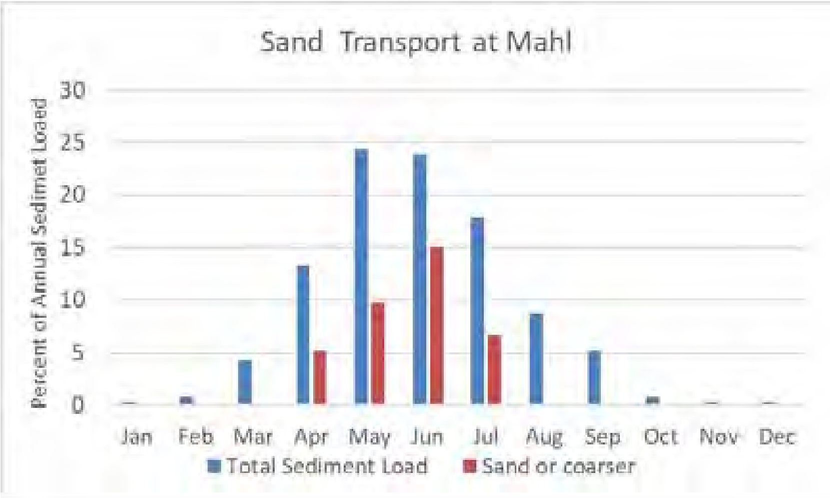
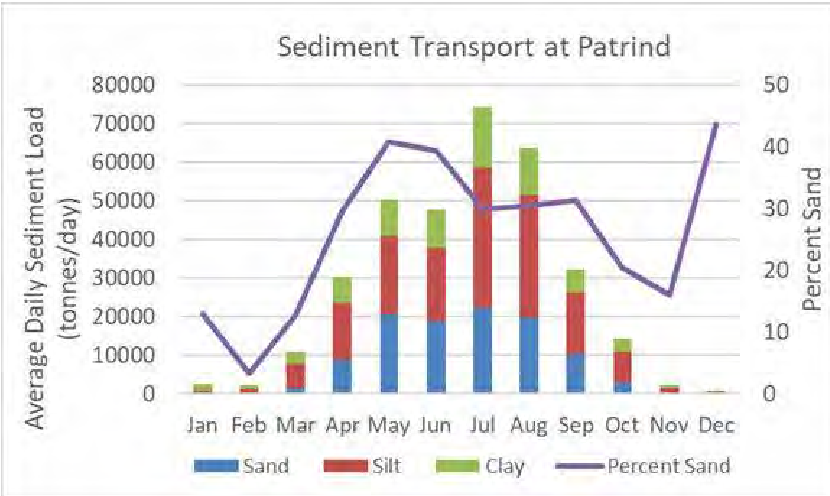


Figure C-21: Grain-size Distribution by Month at Patrind HPP Site in the Kunhar River



C.6.5 Conclusions

The key findings of the sediment audit are outlined below:

- In their natural state, the main rivers in the Jhelum-Poonch Basins have sufficient energy to transport the material being 'shed' by the rapidly uplifting mountainous terrain, which has resulted in deeply incised and steep valleys with limited accumulation of alluvial deposits.
- The Neelum River is the largest single source of sediment in the Neelum-Jhelum Basin, contributing almost half of the sediments to the lower Jhelum River and more than a third of the sediment is transported to Mangla Reservoir. The remaining sediments in the lower Jhelum River are contributed by the middle Jhelum and Kunhar rivers, and the area draining to the Mahl and Azad Pattan HPP sites. The Poonch River contributes about 24% of the load entering the Mangla Reservoir.
- There is a poor correlation between river flow and sediment transport because sediment transport is governed more by the delivery of sediment to the rivers than by the transport capacity of the rivers, and sediment inputs can vary markedly over short distances.
- May-June tends to be a period of peak sediment transport, because it coincides with a period of high erodibility of the mountain slopes.

The sediment audit provides a basin overview using existing sediment data for the basin, but there is a lack of information about geomorphic processes at the local scale. These localized relationships drive in-channel and riparian habitat diversity and condition, and hence have a controlling influence over biodiversity and ecosystem condition.

A land cover analysis was conducted for the entire Jhelum-Poonch basin to detect changes in land cover over a period of 21 years (1993-2014). Landsat satellite images of moderate spatial resolution (30m) were used to detect and illustrate the changes.

C.A.1 Data Sources

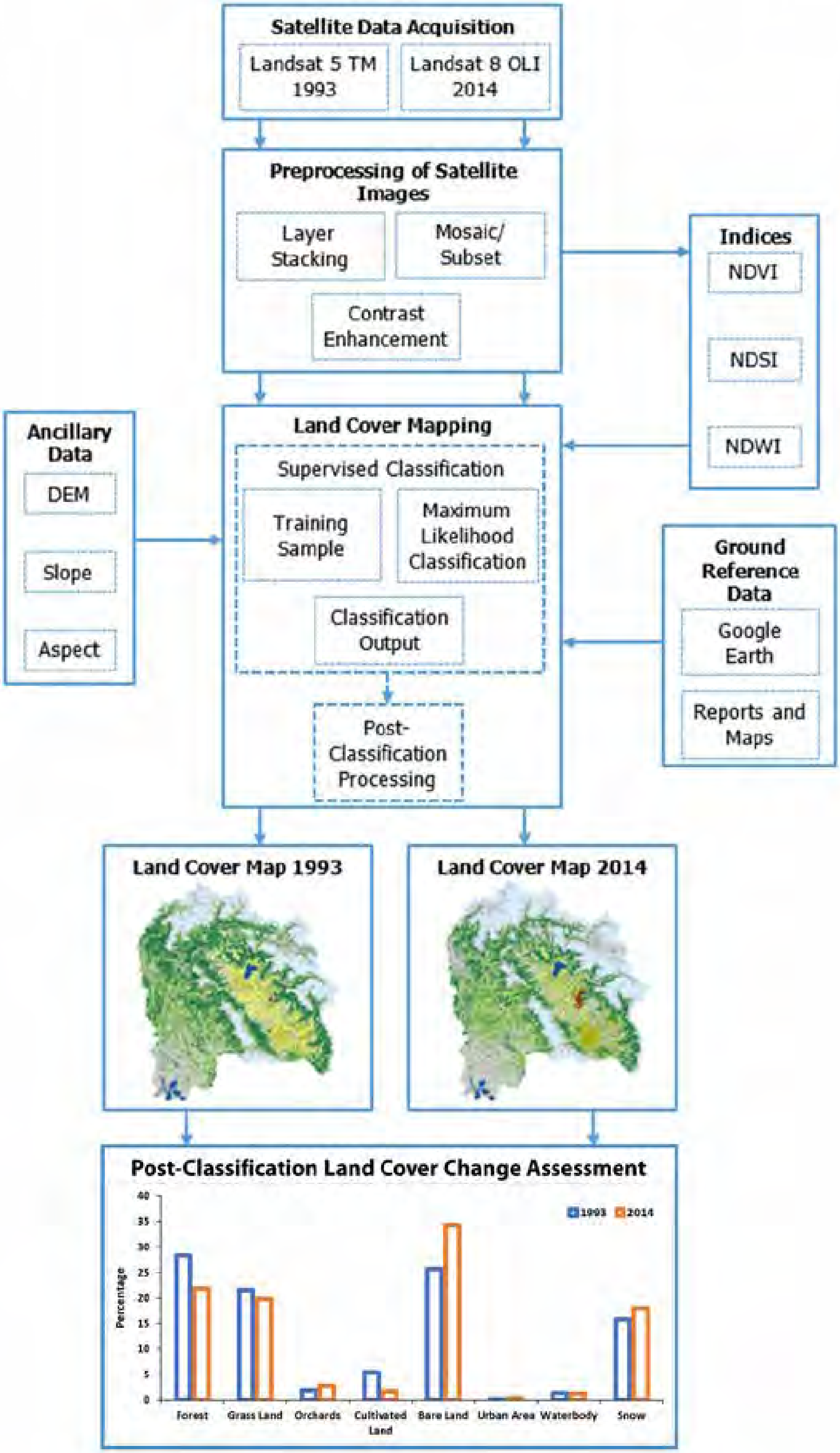
Data from two Landsat sensors was used to assess changes in land cover in the basin. Surface reflectance products of Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Manager (OLI) were downloaded for the month of June 1993 and 2014 respectively. Both TM and OLI sense the earth reflected radiations in different ranges of the electromagnetic spectrum and thus are commonly known as multispectral sensors. These datasets are freely available at United States Geological Survey's USGS's Earth Explorer website (https://earthexplorer.usgs.gov). During the download phase, only those images were selected which had a cloud cover of less than 10%. Moreover, datasets for the same month for both timeframes were selected. Overall, four satellite scenes were required for each year to cover the entire study area. The time threshold for scene selection was ±20 days. The month of June was selected to conduct the land cover analysis primarily because it contained images with minimum cloud cover and also because images were available for both years (1993 and 2014) for the month of June. Landsat data is often used for such studies because it is free of cost, and also provides good temporal coverage. **Figure C.A.1** provides an overview of the process followed in a flow diagram. **Table C.A.1** gives the list of Landsat scenes used.

Elevation data of 30m spatial resolution was obtained from Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) which is freely available at Earth Explorer website (https://earthexplorer.usgs.gov). Slope and aspect datasets were generated by processing SRTM DEM in ArcGIS software.

Table C.A.1: Specifications of Satellite Scenes

Satellite Sensor	Spatial Resolution (m)	Spectral Bands Used (wavelength in micrometers)	Path/Row	Acquisition Date
Landsat 5 TM	30	Blue (0.45-0.52) Green (0.52-0.60) Red (0.63-0.69) NIR (0.76-0.90) SWIR-1 (1.55-1.75) SWIR-2 (2.08-2.35)	149/036	12 June 1993
			149/037	
			150/036	19 June 1993
			150/037	
Landsat 8 OLI	30	Blue (0.452-0.512) Green (0.533-0.590) Red (0.636-0.673) NIR (0.851-0.879) SWIR-1 (1.566-1.651) SWIR-2 (2.107-2.294)	149/036	06 June 2014
			149/037	
			150/036	13 June 2014
			150/037	

Figure C.A.1: Flow Diagram of Land Cover Change Analysis



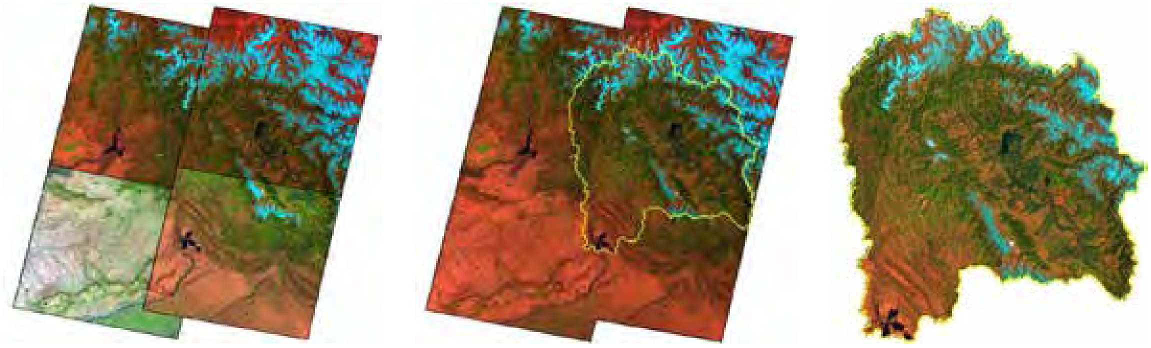
C.A.2
Image Processing and Land Cover Mapping

Earth Resources Data Analysis System (ERDAS) Imagine 2014 was used as a primary image processing software. ArcGIS 10.4 was also utilized on a need basis. The preprocessing phase was started by importing layers into the ERDAS native format. Each of the downloaded surface reflectance products (scenes) were provided in the form of individual spectral bands. These bands were combined to build multispectral images by using a layer stacking process. Next, four satellite scenes for each year which together covered the entire study area were mosaicked for each year. Once mosaicking was completed, the mosaicked images were clipped over the study area (**Figure C.A.2**).

Mosaicked images had a very low contrast which caused difficulty in interpreting different land cover features. Moreover, to perform a change analysis at two different times, it is important to have an equitable contrast configuration for satellite images of both dates. This objective was achieved by using available histogram matching techniques (**Figure C.A.3**).

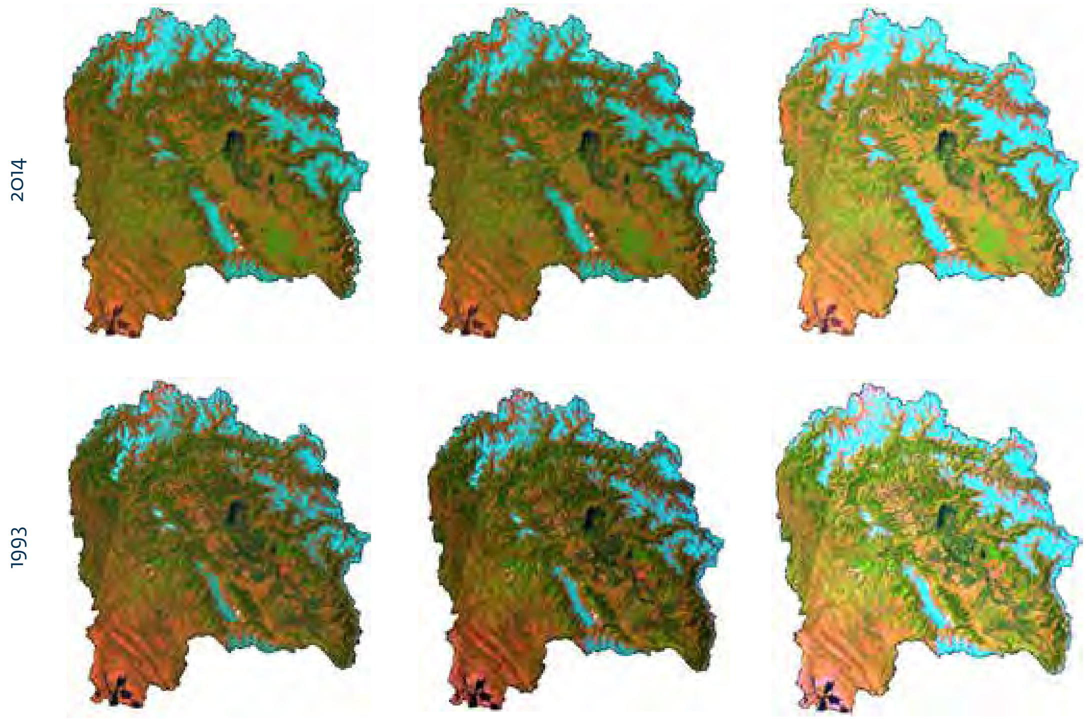
Landsat OLI image for 2014 had a better contrast, and the histogram of Landsat TM 1993 image was matched with the one of Landsat OLI 2014. After histogram matching, the contrast of both images was enhanced by a 1.5 standard deviation.

Figure C.A.2: Satellite Scenes Mosaicking and Clipping



Four Multispectral Images (Year:1993, RGB:742) | Mosaicked Multispectral Image | Satellite Image clipped over Study Area

Figure C.A.3: Scenes Contrast Enhancement



Original Image (RGB:742) | Histogram Matched | 1.5 std Contrast

The next step following the preprocessing of Landsat images was to identify the land cover classes. These classes are listed in **Table C.A.2**.

Table C.A.2: Description of Land Cover Classes

No.	Land cover Class	Description
1	Forest and Scrubs	Contains, coniferous and broadleaf forests and scrubs (thick and sparse)
2	Grasses and Sparse Vegetation	Contains grasses, shrubs, herbs and very sparse vegetation
3	Orchards	Contains orchards
4	Cultivated Cropland	Contains those areas of cropland which were cultivated at the time of imaging
5	Urban Areas	Contains urban areas which were picked by an automatic process
6	Bare land	Contains bare land (including fallow agriculture land) bare rocks
7	Waterbody	Contains rivers, lakes and other water reservoirs
8	Snow and Ice	Contains snow, ice and glaciers

Two most commonly used techniques to classify coarse and moderate resolution satellite images are: unsupervised classification and supervised classification. In unsupervised classification, pixels are grouped into 'clusters' based on their properties and then users merge those clusters and assign classes to clusters based on their specific needs. Two prominent clustering algorithms for unsupervised classification are K-means and ISODATA.

Supervised classification algorithms, on the other hand, use experts' input to classify satellite images. In this approach, the user selects representative samples for each land cover class. The software then uses these 'training sites' and applies them to the entire image. The commonly used supervised classification algorithms are 'maximum likelihood' and 'minimum-distance' classification. For the purpose of the current study, supervised classification using maximum likelihood algorithm was performed. The Landsat satellite scene for the year of 2014 was first considered to perform supervised classification. More than 100 training samples were collected from the entire study area. Homogeneous regions for each land cover class were identified to compile training sites. On average, a minimum of 20-25 training samples were taken for each of the land cover types.

A greater number of training samples were taken for the dominating land cover classes. Visual interpretation techniques and as well as google earth was used to identify areas for training samples. In addition, all the training samples were evaluated by sketching their spectral signatures (**Figure C.A.5**). **Figure C.A.4** shows a unique spectral curve for each land cover feature based on its reflectance characteristics against electromagnetic spectrum.

Figure C.A.4: Landsat Clipped Images of Different Years

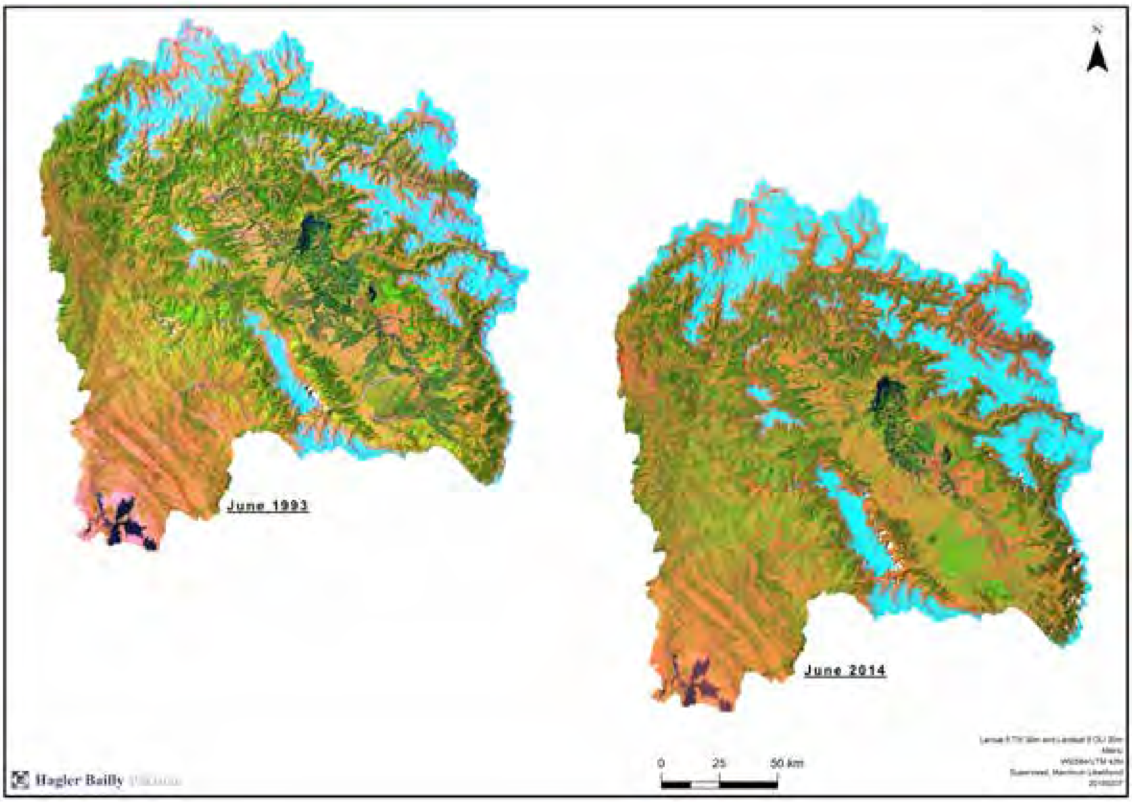
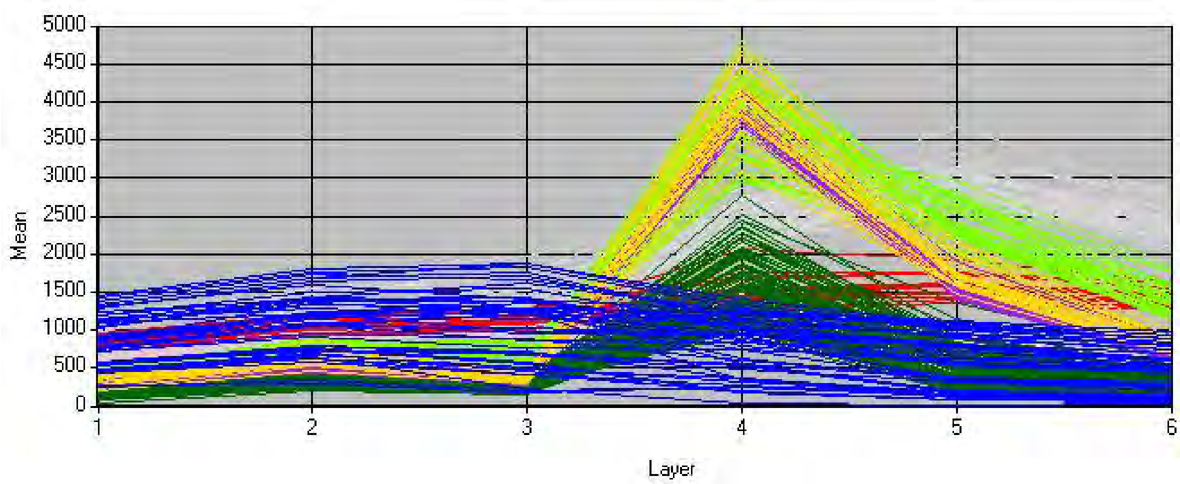


Figure C.A.5: Spectral Signatures of Different Land cover Features



A few of the land cover classes, like water and snow, were extracted by using different indices like Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Normalized Difference Snow Index (NDSI).

Once the training samples were compiled, the Maximum Likelihood algorithm was executed to classify the image. The classified image was then evaluated by using expert knowledge, google earth, and secondary data like reports and historic land cover maps. Specific areas which were not correctly classified were delimited and more training samples were taken at those sites before running the algorithm again. The process was repeated until satisfactory results were achieved. Post-classification processing techniques were used to apply minor modifications/ corrections in the classified satellite images. The land cover types which were overlapping and mixing (like barren rocks and urban area) were separated by using elevation, slopes and aspect values. In the final stage, all land cover classes were combined together and a land cover map for the year 2014 was developed.

The knowledge gained through the classification of the 2014 satellite image was applied to the classification of the 1993 landsat image. The procedure adopted for 2014 satellite image classification was replicated to develop land cover map for the year 1993. In the end, land cover statistics calculated for both land cover maps and results were compiled in MS Excel for further interpretation.

Table C.A.3: Classification Accuracy Assessment for Land Cover 2014

Classification Accuracy Matrix

Classification Data	Reference Data: Forest	Grasses	Orchards	Irrigated Land	Builtup Area	Bareland	Waterbody	Snow and Ice	Total	User Accuracy
Forest	40	4	0	0	0	0	0	0	44	91
Grasses	9	29	2	0	0	0	0	0	40	73
Orchards	1	1	8	0	0	0	0	0	10	80
Irrigated Land	1	0	0	9	0	0	0	0	10	90
Builtup Area	0	0	0	0	7	3	0	0	10	70
Bareland	10	6	1	0	1	48	0	3	69	70
Waterbody	0	0	0	0	0	0	10	0	10	100
Snow and Ice	0	0	0	0	0	0	1	35	36	97
Total	61	40	11	9	8	51	11	38	229	
Producer Accuracy	66	73	73	100	88	94	91	92		

Overall Accuracy(%)	81	Kappa Coefficient	0.77

C.A.3 Accuracy Assessment

The accuracy of the land cover map for 2014 was assessed by using the stratified random technique in ArcGIS. The stratified random method creates points that are randomly distributed within each class, where each class has a number of points proportional to its relative area (**Table C.A.3**). The overall accuracy was 81% with a kappa coefficient value of 0.77.

C.A.4 Challenges and Recommendations

While an effort has been made to develop an accurate land cover map for the basin, some uncertainties still exist as a result of using low-resolution satellite images. This has led to issues in identifying some land cover classes. For instance, the algorithm used was unable to separate bare land from fallow agriculture land. Similarly, the algorithm was able to detect only those urban areas which had thick built-up configurations, whereas urban areas with sparse built-up configuration were classified as bare land.

Another challenge was the absence of ground truthing during the land cover classification process. Although some sources like google earth provide partial ground referenced data, ground truthing is important, especially in areas where confusion about the land cover classes exist.

Based on the challenges faced and lessons learnt from this land cover change analysis, given below are some recommendations for additional studies.

- It is recommended that high-resolution satellite imagery be used for land cover change analysis. This will not only increase the accuracy of land cover classification, but also allow experts to increase the number of land cover classes - for instance by detecting fallow land, separating scrubs from forests, separating coniferous and broadleaf forests, and identifying smaller urban areas.
- Instead of undertaking a land cover change analysis for two fixed time slots, it is recommended that a comprehensive analysis be carried out for an entire month or season. This will allow a better understanding of phenomena such as change in cultivation patterns, changes in snow cover, as well as the difference between fallow land and barren land in that specific year.
- Field surveys should be undertaken to ground truth the information gathered from satellite images, especially in areas where there is any confusion about the land cover class.

Annex D

Ecological Importance of Zones in Area of Management

This section provides an overview of both the aquatic and terrestrial ecological resources reported from the Area of Management. The major impact of hydropower project construction and operation will be on the aquatic ecological resources, however, the terrestrial ecological resources are likely to suffer harm due to project infrastructure construction as well as due to construction of grid stations and electricity transmission lines.

D.1
Ecological Zones in Area of Management

There are four important and distinct water bodies in the basin namely, Neelum River, Kunhar River, Jhelum River and Poonch River. The fish fauna of these rivers is briefly described in the following sections. This section divides these rivers into different zones based on ecological similarities.

Fish abundance and diversity is dependent on the nature of the water habitat, water temperature, water quality, conditions of the river-bed, as well as climatic conditions. Thus, the physical and chemical characteristics of a water body have a direct relationship with the type of fish that will be found. Based on similarities in physical and chemical characteristics as well as the diversity of fish fauna, the rivers of the Area of Management can be divided into the following zones.

- Zone A - Kunhar River (Lulusar Lake to Paras Town)
- Zone B - Kunhar River (Paras Town to Muzaffarabad)
- Zone C - Neelum River (Taobat to Dhudhnial)
- Zone D - Neelum River (Dhudhnial to Muzaffarabad)
- Zone E - Jhelum River (Chakothi to Muzaffarabad)
- Zone F – Muzaffarabad city
- Zone G - Jhelum River (Downstream Muzaffarabad to confluence of Mahl River)
- Zone H - Jhelum River (Confluence of Mahl River to Mangla Reservoir)
- Zone I - Mahl River (Mahl River from Nar Sher Khan to confluence of Jhelum River)
- Zone J - Poonch River

Socio-economic similarities have also been taken into consideration for this zone delineation.

The Mangla reservoir has been created as a result of operation of the Mangla Dam. Since it is not a natural waterbody, the Mangla Reservoir has been excluded from the Area of Management.

Figure D-1 shows the temperature variations and the distribution of fish fauna in the rivers of the Area of Management. **Figure D-2** shows the delineated ecological zones.

It should be noted that ecological similarities are not bound by political boundaries and the ecological zones are likely to extend into India. However, for ease of reference and because they are not included in the Area of Management, these zones are shown to begin at the Line of Control.

A list of the fish species from the Area of Management is given in Annex D.A, *Fish Species of Jhelum-Poonch Basin*, of **Annex D**.

Figure D-1: Temperature Delineations and Distribution of Fish Fauna in the Jhelum-Poonch Basin

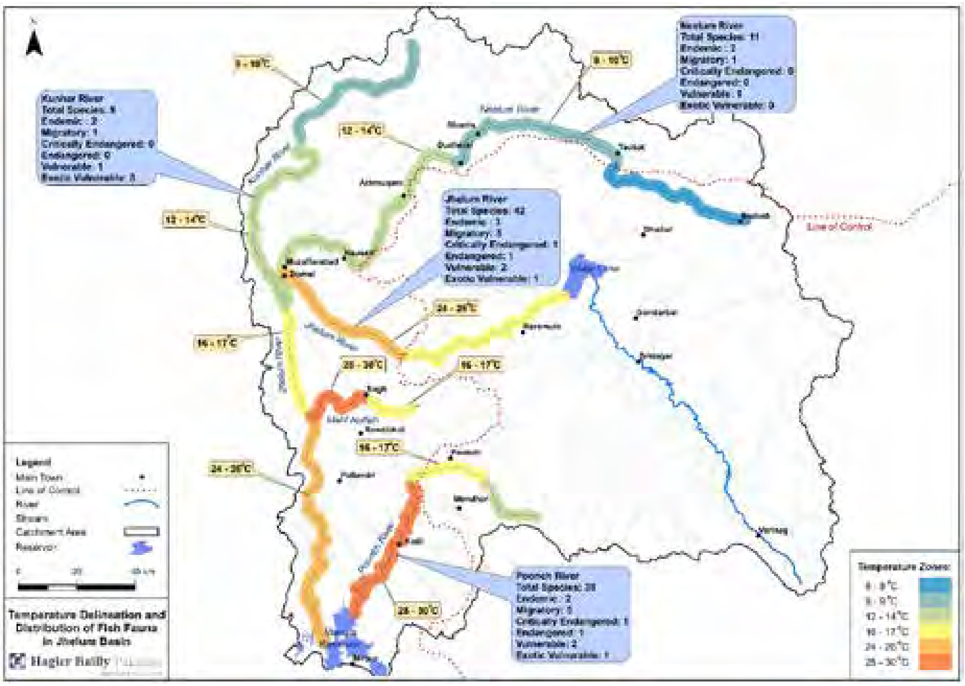
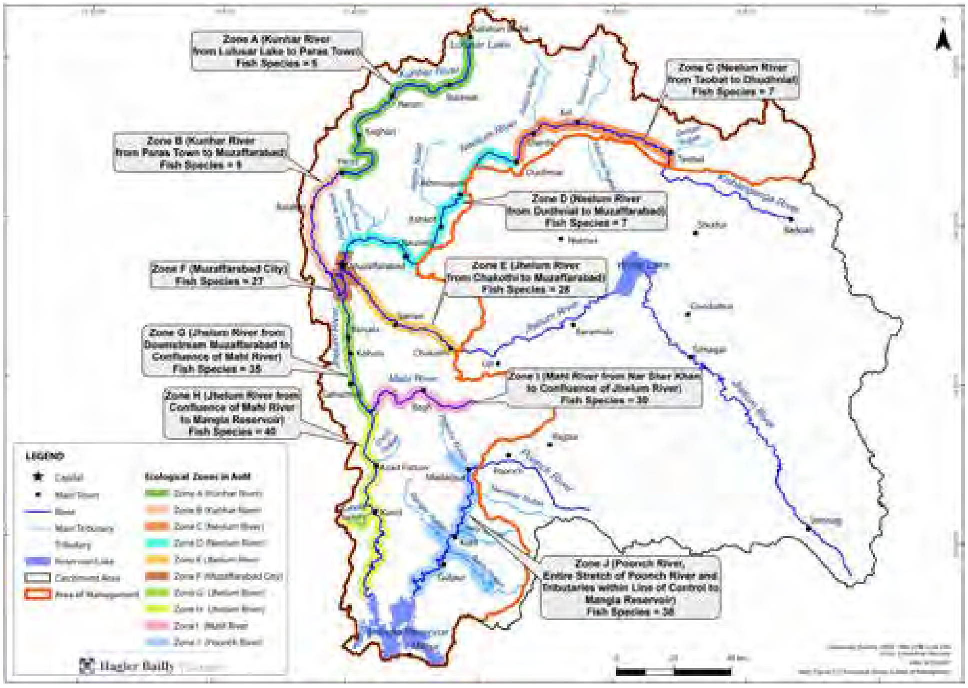


Figure D-2: Ecological Zones in Area of Management



D.2
Ecological Importance of Zones

The different river zones identified in the previous section vary in their sensitivity to hydropower development. The sensitivity can be assessed by following the same methodology as outlined in the SEA of Hydropower Development in AJK.[1] The ecological importance of each zone can be assessed using the following indicators:

- Fish Diversity – This refers to the type and number of fish species reported. Greater fish diversity is indicative of conditions conducive for fish feeding, breeding and growth[2]
- Conservation Status of Species - These may include species that are listed in the IUCN Red List 2018[3] or those that are endemic to the Jhelum-Poonch basin[4]
- Status as Protected Area - A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values.[5] Protected areas may include wildlife sanctuaries or national parks declared by the local government. Also included are protected areas declared by IUCN Protected Areas Management[6] and those that contain a critical habitat as designated by the International Finance Corporation (IFC) Performance Standards.[7]

[1] IUCN Pakistan, 2014, Strategic Environmental Assessment of Hydropower Development in AJK, Report, jointly produced by Hagler Bailly Pakistan and Dr David Annandale as part of their contractual obligations with IUCN.

[2] Rafique, M. (2007). Biosystematics and distribution of the freshwater fishes of Pakistan with special references to the subfamilies Noemacheilinae and Schizothoracinae. Ph.D. dissertation, UAAR. Pp 220.

[3] The IUCN Red List of Threatened Species™ provides taxonomic, conservation status and distribution information on plants and animals that have been globally evaluated using the IUCN Red List Categories and Criteria. This system is designed to determine the relative risk of extinction, and the main purpose of the IUCN Red List is to catalogue and highlight those plants and animals that are facing a higher risk of global extinction (i.e. those listed as Critically Endangered, Endangered and Vulnerable). The IUCN Red List also includes information on plants and animals that are categorized as Extinct or Extinct in the Wild; on taxa that cannot be evaluated because of insufficient information (i.e., are Data Deficient); and on plants and animals that are either close to meeting the threatened thresholds or that would be threatened were it not for an ongoing taxon-specific conservation programme (i.e., are Near Threatened).

[4] Endemism is the ecological state of being unique to a defined geographic location, such as an island, country or other defined zone, or habitat type.

[5] Dudley, N. (ed.) (2008) Guidelines for Appling Protected Areas Management Categories. IUCN: Gland, Switzerland.

[6] IUCN protected area management categories classify protected areas according to their management objectives. The categories are recognised by international bodies such as the United Nations and by many national governments as the global standard for defining and recording protected areas and as such are increasingly being incorporated into government legislation. Available at official website of IUCN: http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/ Accessed on 16 September 2017.

[7] International Finance Corporation (IFC) The World Bank Group. 2012, Policy on Social and Environmental Sustainability, Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources. January 2012.

- Economic Value of Fish - Fishing not only provides food for local consumption but is also a source of livelihood for individuals involved in commercial fishing as well as for individuals working in the food industry (such as processing and packaging of edible fish species). Fish are also important for recreational and sport fishing and boost tourism.

The physical and biological characteristics of each zone are discussed below followed by a discussion about the sensitivity rating of each zone. The zones are assessed and ranked on a scale of 'high', 'medium' and 'low' sensitivity for each of the aforementioned indicators. Together these indicators combine to give a picture of the ecological sensitivity of each zone.

Besides, the above indicators, some river ecosystems are important because they provide a breeding ground, or migratory route for other fish species that abound in either upstream or downstream river zones. Therefore, they are important for maintaining the connectivity of fauna of one river zone with another. This aspect has also been considered in assessing the ecological sensitivity of each zone.

D.2.1 Zone A – Kunhar River from Lulusar to Paras Town

Physical Characteristics

The mean water temperature varies from 8-10°C in this zone of Kunhar River. In summer a temperature of 12 °C has also been recorded.[8] The river is mainly narrow and shallow and the river bed is generally gravely, cobbly or rocky.

Biological Characteristics

Common fish species reported from this zone include the Alwan Snow Trout, Kashmir Hillstream Loach and Himalayan Catfish. Kashmir Hillstream Loach, though common in the area, is a restricted range fish and not recorded outside the Jhelum-Poonch basin.

The other common species are Brown Trout and Rainbow Trout. These introduced fish species have been reported from the entire length of this zone and have high commercial value. Alwan Snow Trout is also locally consumed for food.

Photographs of some fish species found in Zone A are given in **Figure D-3**.

Discussion

Fish Diversity: Only five fish species have been reported from this zone, therefore the overall fish diversity is low due to cold climatic conditions in this zone. These fish are adapted to the cold weather conditions and sensitive to drastic temperature variations.

Economic Importance of Fish: Three of the fish species reported from this zone are economically important - the Brown Trout and Rainbow Trout have high

Figure D-3: Photographs of fish species reported from Zone A

a) Rainbow Trout *Oncorhynchus mykiss*

b) Alwan Snow Trout *Schizothorax richardsonii*

c) Kashmir Hillstream Loach *Triplophysa kashmirensis*

d) Himalayan Catfish *Glyptosternum reticulatum*

[8] Hagler Bailly Pakistan (HBP), 2017. *Draft Environmental and Social Impact Assessment (ESIA) of Balakot Hydropower Project*. Prepared for Asian Development Bank

commercial value and Alwan Snow Trout is locally consumed as food fish. The economic importance of fish in this zone can be rated as Medium.

Conservation Importance of Fish Species: Although Alwan Snow Trout is widely distributed along the Himalayan foothills and previous studies have indicated that it is abundantly and commonly found, recent observations over the last 5 to 10 years indicate drastic declines in many areas of its range due to introduction of exotics, damming and overfishing. Therefore, it has been listed as Vulnerable in the IUCN Red List.[9] However, no Endangered or Critically Endangered fish species has been reported from this zone. The Kashmir Hillstream Loach has restricted ranges and is endemic to the Jhelum-Poonch basin. However, the population of Kashmir Hillstream Loach in this zone is low, therefore the conservation importance of the fish species in Zone A is Low.

Protected Area: Some parts of this zone are included in the Lulusar-Dudipatsar National Park, which is a protected area.

D.2.2 Zone B – Kunhar River from Paras Town to Muzaffarabad

Physical Characteristics

Kunhar River is a cool water river. The water temperature in the main Kunhar River ranges between 12 – 14°C during summer, while a temperature of up to 25°C has been recorded in some of the tributaries of the river during the summer season.

Biological Characteristics

Common and abundant fish species reported from this zone include Alwan Snow Trout, Kashmir Hillstream Loach, Himalayan Catfish, Nalbant's Loach and Flat Head Catfish. The species Alwan Snow Trout as well as the restricted range Kashmir Hillstream Loach have been reported from throughout the stretch of this zone.

Other species reported from this zone of the Kunhar River include Rainbow Trout, Arif's Loach and Stone Loach. The Rainbow Trout is an exotic species and has high commercial value. Alwan Snow Trout is locally consumed as food fish.

Photographs of some fish species reported from Zone B are given in **Figure D-4**.

Discussion

Fish Diversity: A total of nine fish species have been reported from this zone. Therefore, the overall fish diversity is low due to cold to cool climatic conditions in this zone. Most of these fish are adapted to the cold weather conditions and sensitive to drastic temperature variations.

Figure D-4: Photographs of fish species reported from Zone B

a) Kashmir Hillstream Loach *Triplophysa kashmirensis*

b) Alwan Snow Trout *Schizothorax richardsonii*

c) Flat Head Catfish *Glyptothorax pectinopterus*

d) Nalbant's Loach *Schistura nalbanti*

[9] Vishwanath, W. 2010. *Schizothorax richardsonii*. The IUCN Red List of Threatened Species 2010: e.T166525A6228314. http://dx.doi.org/10.2305/IUCN.UK.2010-4.RLTS.T166525A6228314.en. Downloaded on 17 April 2018.

Economic Importance of Fish: Two of the fish species reported from this zone are economically important - the Rainbow Trout has high commercial value and Alwan Snow Trout is also locally consumed as food fish. The economic importance of the fish in this zone can be rated as Medium.

Conservation Importance of Fish Species: No Endangered or Critically Endangered fish species has been reported from this zone. The Alwan Snow Trout is listed as Vulnerable in the IUCN Red List. The Kashmir Hillstream Loach and Nalbant's Loach have restricted ranges and are endemic to the Jhelum-Poonch basin. It can, therefore, be deduced that the conservation importance of the fish species in this zone is Medium.

Protected Area: No segment of the Kunhar River in this zone is legally protected.

D.2.3 Zone C – Neelum River from Taobat to Dudhnial

Physical Characteristics

Mean water temperature varies between 6-7ºC. Dissolved oxygen in the water ranges from 8-10 mg/l, pH ranges from 6-7 and TDS (Total Dissolved Solids) range from 50-100 ppm. The river bed is generally gravely, cobbly or rocky. The river is wide and shallow ranging from 1-2 m. The water velocity ranges from 0.5-2m/s. All these physical factors indicate a cold-water river inhabiting cold water fish fauna.

Biological Characteristics

Common and abundant fish species reported from this zone of Neelum River include Brown Trout, Alwan Snow Trout, Kashmir Hillstream Loach and Himalayan Catfish. The species Alwan Snow Trout, Kashmir Hillstream Loach and Himalayan Catfish are found throughout the entire length of this zone.

The species High Altitude Loach and Tibetan Snow Trout are only found in the upper reaches of the river and not recorded below the town of Sharda. Brown trout, though an exotic species, is considered an esteemed fish and has high commercial value. Similarly, Alwan Snow Trout and Tibetan Snow Trout are locally consumed as food fish.

Photographs of some fish species reported from Zone C are given in **Figure D-5**.

Discussion

Fish Diversity: Only 7 fish species have been reported from this zone, therefore the overall fish diversity is low due to cold climatic conditions in this zone. These fish are adapted to the cold weather conditions and sensitive to drastic temperature variations.

Economic Importance of Fish: Three of the fish species reported from this zone are economically important - the Brown Trout has high commercial value and Alwan Snow Trout and Tibetan Snow Trout are locally consumed as food fish. The economic importance of fish in this zone can be rated as Medium.

Figure D-5: Photographs of the Fish Species found in Zone C

a) Brown Trout *Salmo trutta fario*

b) Alwan Snow Trout *Schizothorax richardsonii*

c) High Altitude Loach *Triplophysa stoliczkai*

d) Himalayan Catfish *Glyptosternum reticulatum*

Conservation Importance of Fish Species: The Alwan Snow Trout is listed as Vulnerable in the IUCN Red List. However, no Endangered or Critically Endangered fish species has been reported from this zone. The Kashmir Hillstream Loach, a restricted range species endemic to the Jhelum-Poonch basin is an abundant species of this zone. It can, therefore, be deduced that the conservation importance of the fish species in Zone C is Medium.

Protected Area: Some parts of this zone are included in the Musk Deer National Park which is a protected area (National Park).

D.2.4
Zone D – Neelum River from Dudhnial to Muzaffarabad

Physical Characteristics

Several tributaries join this section of the Neelum River. As a result, the water volume increases and so does the water speed. The river bed is mostly devoid of gravel or cobbles and is dominated by rocky bed. Mean water temperature is 8-10ºC. Dissolved oxygen ranges between 8-10 mg/l and pH ranges between 6 -7.

Biological Characteristics

Species reported from this zone of Neelum River include High Altitude Loach, Alwan Snow Trout, Kashmir Hillstream Loach, Himalayan Catfish and Nalbant's Loach.

Figure D-6 shows photographs of some fish species reported from Zone D.

Discussion

Fish Diversity: A total of seven fish species have been reported from this zone. Therefore, the overall fish diversity is low due to cold climatic conditions in this zone. These fish are adapted to the cold weather conditions and are, sensitive to drastic temperature variations.

Economic Importance of Fish: Only one fish species - the Alwan Snow Trout - reported from this zone is economically important. This is locally consumed as food fish. The economic importance of fish in this zone can be rated as Low.

Conservation Importance of Fish Species: The Alwan Snow Trout is listed as Vulnerable in the IUCN Red List. However, no Endangered or Critically Endangered fish species has been reported from this zone. The Kashmir Hillstream Loach and Nalbant's Loach have restricted ranges and are endemic to the Jhelum-Poonch basin. It can, therefore, be deduced that the conservation importance of the fish species in the Zone D is Medium.

Protected Area: There is no protected area in this zone.

Figure D-6: Photographs of the Fish Species reported from Zone D of Neelum River

a) Kashmir Hillstream Loach *Triplophysa kashmirensis*

b) Alwan Snow Trout *Schizothorax richardsonii*

c) Flat Head Catfish *Glyptothorax pectinopterus*

D.2.5
Zone E –Jhelum River from Chakoti to Muzaffarabad

Physical Characteristics

The temperature in this zone varies between 6°C in the winter and 24°C during summer. The Dissolved Oxygen ranges from 6-7 mg/l as the river remain turbid throughout the monsoon season. The river bed varies with patches of sand and gravel. However, cobbly and rocky habitat predominates in most stretches of the river.

Biological Characteristics

The water temperature in this zone of Jhelum River remains around 24°C during the summer season. Due to this warm water regime, the fish fauna from downstream river stretches migrate to this zone in the summer. The common fish species reported from this zone include Alwan Snow Trout, Indus Garua, Pakistani Labeo, Kunar Snow Trout, Suckerhead, Kashmir Latia, Pakistani Baril, Naziri Catfish and Kashmir Catfish.

Figure D-7 shows some photographs of fish species reported from Zone E.

Discussion

Fish Diversity: A total of 28 fish species has been reported from this zone including members of Family Balitoridae, Cyprinidae and Sisoridae. Therefore, the overall fish diversity can be rated as High.

Economic Importance of Fish: At least seven fish species reported from this zone are commercially important. These include Alwan Snow Trout, Indus Garua, Pakistani Labeo, Sattar's Snow Trout *Schizothorax curvifrons*, Kunar Snow Trout *Schizothorax labiatus*, Suckerhead and Chirruh Snow Trout *Schizothorax esocinus*. The economic importance of fish species in this zone is Medium.

Conservation Importance of Fish Species: Kashmir Catfish, recorded from this zone is listed as Critically Endangered in the IUCN Red List 2018 while the Alwan Snow Trout is listed as Vulnerable. The species Kashmir Hillstream Loach, Kashmir Catfish and Nalbant's Loach reported from this zone are restricted range species and endemic to the Jhelum-Poonch basin. This zone is an important habitat of the Kashmir Catfish habitat and the largest global population of this fish is found in this zone. In addition, there are four migratory species reported from this zone i.e. Alwan Snow Trout, Pakistani Labeo, Indus Garua, Suckerhead.

Due to the presence of one Vulnerable, one Critically Endangered, three restricted range and four long distance migratory fish species, the conservation importance of fish species in this zone is High.

Protected Area: There is no protected area in this zone.

Connectivity: Due to warm water regime in this river zone, the fish species from downstream river reaches

Figure D-7: Fish Fauna reported from Zone E, Jhelum River

a) Pakistani *Labeo dyocheilus*

b) Himalayan Catfish *Glyptosternum reticulatum*

c) Indian Loach *Botia lohachata*

d) Pakistani Baril *Barilus pakistanicus* migrate to this zone in the summer. These species include Alwan Snow Trout, Suckerhead, Pakistani Labeo, and Indus Garua. Thus, this zone of Jhelum River is important for supporting the fish species found in downstream sections of the river and plays a role in connectivity with downstream ecosystems.

D.2.6 Zone F –Muzaffarabad City

Physical Characteristics

The water temperature of River Jhelum in this zone remains moderate and does not rise beyond 18°C in the summer. This is because this zone is at the confluence of three rivers Neelum River, Kunhar River and Jhelum River. Mean monthly flow rate of the River Neelum exceeds that of River Jhelum in the peak summer months and this cold water from Neelum River significantly affects the water temperature of this zone.

Biological Characteristics

The common fish species found in this zone include Alwan Snow Trout, Suckerhead, Kashmir Latia, Pakistani Baril, Naziri Catfish, Flat Head Catfish, Bhed Catfish, Pakistani Labeo and Nalbant's Loach.

Photographs of some fish species reported from Zone F are given in **Figure D-8**.

Discussion

Fish Diversity: A total of 27 fish species has been reported from this zone. Therefore, the overall fish diversity can be rated as High.

Economic Importance of Fish: At least seven fish species found in this zone are commercially important. These include Alwan Snow Trout, Indus Garua, Pakistani Labeo, Sattar's Snow Trout, Kunar Snow Trout, Common Carp, and Chirruh Snow Trout. The economic importance of fish species in this zone is Medium.

Conservation Importance of Fish Species: Kashmir Catfish, recorded from this zone is listed as Critically Endangered in the IUCN Red List. However, its population is very low. The Vulnerable Alwan Snow Trout is abundant species in this zone. The restricted range species, Kashmir Hillstream Loach has a very small population in this zone and has been observed only rarely. Nalbant's Loach is also a restricted range species reported from this zone. In addition to these restricted range species, there are four migratory species reported from this zone i.e. Alwan Snow Trout, Pakistani Labeo, Indus Garua, Suckerhead. The conservation importance of fish species in this zone is High.

Protected Area: There is no protected area in this zone.

Figure D-8: Fish Fauna reported from Zone F, Muzaffarabad City

a) Pakistani *Labeo dyocheilus*

b) Himalayan Catfish *Glyptosternum reticulatum*

c) Indian Loach *Botia lohachata*

d) Pakistani Baril *Barilus pakistanicus*

D.2.7
Zone G – Jhelum River from downstream Muzaffarabad to confluence of Mahl River

Physical Characteristics

The water in the Jhelum River downstream of Muzaffarabad is cooler compared to upstream Muzaffarabad due to confluence of the Jhelum River with Neelum and Kunhar River which also leads to an increase in water discharge. The river also runs through more gorges in this zone. Water temperature of River Jhelum below Muzaffarabad remains moderate and does not rise beyond 18°C however the water temperature in the lower reaches (near the confluence of Mahl River) of this zone reaches 23°C in the summers.

Three temperature regimes viz., warm water regime in the river Jhelum above Muzaffarabad, cold water regime in the river Neelum and Kunhar and a cool water regime in the river Jhelum below Muzaffarabad help the fish fauna to disperse in different parts of the rivers according to their optimal temperature choice.

Biological Characteristics

The common fish species reported from this zone of the Jhelum River include Alwan Snow Trout, Suckerhead, Kashmir Latia, Pakistani Baril, Nazri Catfish, Nalbant's Loach, Havelian Loach.

Photographs of some fish species reported from Zone G are given in **Figure D-9**.

Discussion

Fish Diversity: A total of 35 fish species has been reported from this zone including members of Family Balitoridae, Cyprinidae and Sisoridae. The overall fish diversity can be rated as High.

Economic Importance of Fish: The Golden Mahseer, Alwan Snow Trout, Pakistan Labeo, Indus Garua and Macropogon Snow Trout are commercially important edible fish species found in this zone. However, Golden Mahseer is rare and has only been reported from the lower parts of this zone. The economic importance of fish fauna of this zone can be rated as Medium.

Conservation Importance of Fish Species: Four fish species reported from this zone are listed in the IUCN Red List 2018. The Kashmir Catfish is listed as Critically Endangered, Golden Mahseer listed as Endangered while Alwan Snow Trout and Twin-banded Loach are listed as and Vulnerable. Three fish species are restricted range and endemic to the Jhelum-Poonch basin *viz*. Kashmir Hillstream Loach, Nalbant's Loach and Kashmir Catfish. However, the population of Kashmir Catfish is very low and Kashmir Hillstream Loach is rare in this zone. There are five long distance migratory species reported from this zone i.e., Golden Mahseer, Alwan Snow Trout, Pakistani Labeo, Indus Garua, Suckerhead. The conservation importance of the fish species in this zone can be rated as High due to presence of four globally threatened fish species, three restricted range and five migratory fish species.

Protected Area: There is no protected area in this zone.

Figure D-9: Fish Fauna Reported from Zone G, Jhelum River

a) Macropogon Snow Trout *Schizothorax macropogon*

b) Kashmir Catfish *Glyptothorax kashmirensis*

c) Lohachata Loach *Botia lohachata*

d) Havelian Loach *Schistura afasciata*

D.2.8
Zone H –Jhelum River from confluence of Mahl River to Mangla Reservoir

Physical Characteristics

Water temperature in this stretch of the river is quite high and can reach 28-30 °C during summer months. Owing to high temperature and closeness to the Mangla dam, the area is mainly occupied by warm water fish fauna with only a few species representing cool water.

Biological Characteristics

A total 40 fish species has been reported from this zone. The common fish species found in this zone include Golden Mahseer, Alwan Snow Trout, Pakistani Labeo, Indus Garua, Pakistani Baril, Naziri Catfish, Spiny Eel *Mastacembelus armatus*, Suckerhead, Kashmir Latia.

Figure D-10 shows some photographs of fish species reported from Zone H.

Discussion

Fish Diversity: A total of 40 fish species has been reported from this zone of Jhelum River including members of Family Balitoridae, Cyprinidae and Sisoridae. This stretch of the river receives the Mahl River draining the Bagh and Arja area. This river stretch is influenced by the Mangla Reservoir and the species Indus Garua, Clown Catfish *Gagata cenia*, and Gora Chela *Securicula gora* represent the reservoir fishes. The Alwan Snow Trout has been reported from this river stretch, however, this zone is the southernmost limit for this fish. The fish diversity of this zone can be rated as High.

Economic Importance of Fish: The commercially important fish fauna of this zone includes the Golden Mahseer, Pakistani Labeo, Indus Garua, Alwan Snow Trout. These commercially important fish species are abundant in this zone. Therefore, the economic importance of fish in this zone can be rated as Medium.

Conservation Importance of Fish Species: The Golden Mahseer is listed as Endangered while Alwan Snow Trout and Twin Banded Loach are listed as Vulnerable in the IUCN Red List. The Golden Mahseer and Alwan Snow Trout are found in greater numbers in the associated tributaries of this zone. Nalbant's Loach is the only restricted range and endemic (to Jhelum-Poonch basin) fish species reported from this zone. In addition, there are five migratory species reported from this zone *viz*. Alwan Snow Trout, Pakistani Labeo, Indus Garua, Suckerhead and Golden Mahseer. The conservation importance of this zone can be rated as Medium.

Protected Area: There is no protected area in this zone.

Figure D-10: Fish Fauna reported from Zone H, Jhelum River at and below the Confluence of Mahl River

a) Indus Garua *Clupisoma garua*

b) Golden Mahseer *Tor putitora*

c) Spiny Eel *Mastacembelus armatus*

d) Kashmir Latia *Crossocheilus diplochilus*

D.2.9
Zone I –Mahl River (from Nar Sher Khan to confluence of Jhelum River with Mahl River)

Physical Characteristics

The elevation of the Mahl River ranges from 500m to 1,300m. As a result of this difference in elevation, the temperature of the river water is cooler at its origin (near the town of Nar Sher Khan i.e. 16-17 °C in summer) while it is warmer near its confluence with Jhelum River (close to 30 °C in summer).

Biological Characteristics

A total 30 fish species have been reported from this zone. The common fish species reported from this zone are Golden Mahseer, Alwan Snow Trout, Pakistani Baril, Naziri Catfish, Suckerhead, Kashmir Latia, Nalbant's Loach.

Of the species reported from Mahl River, the Nalbant's Loach, Golden Mahseer, Alwan Snow Trout are species of special importance.

Photographs of some fish species reported from Zone I are given in **Figure D-11**.

Discussion

Fish Diversity: A total of 30 fish species has been reported from this zone. Mahl River is rich in fish diversity as compared to Neelum and Kunhar River. The high fish diversity reported from Mahl River is due to the topography and water temperature of the Mahl River. The Mahl River flows gently in a vast and flat valley and provides numerous breeding grounds for the reproduction of fish. The fish diversity of this zone can be rated as High.

Economic Importance of Fish: The species included in the IUCN Red List include the Golden Mahseer and Alwan Snow Trout. The other commercially important species are Pakistani Labeo, Spiny Eel and Suckerhead. Some of these species such as Golden Mahseer, Alwan Snow Trout and Pakistani Labeo have very high commercial importance. So overall the economic importance of fish in this zone is Medium.

Conservation Importance of Fish Species: Three species, Golden Mahseer (Endangered), Alwan Snow Trout (Vulnerable) and Twin Banded Loach (Vulnerable) included in the IUCN Red List have been reported from this zone. The conservation importance fish in this zone can be rated as being High particularly because this zone provides a breeding ground for these fish of conservation importance.

Protected Area: The AJK Fisheries and Wildlife Department has proposed that the entire length of the Mahl River be declared as a Protected Area. However, the official notification in this regard is still pending.

D.2.10
Zone J –Entire stretch of Poonch River and Tributaries within Line of Control to Mangla Reservoir

Physical Characteristics

The Poonch River is the warm water river and the

Figure D-11: Photographs of the Fish Species in Zone I, Mahl River

a) Himalayan Catfish Glyptosternum reticulatum

b) Suckerhead Garra gotyla

c) Alwan Snow Trout Schizothorax richardsonii

d) Twin Banded Loach Botia rostrata

water temperature approaches to 30°C during the summer months.

Biological Characteristics

A total 38 fish species has been reported from this zone. The common fish species reported from this zone include Golden Mahseer, Alwan Snow Trout, Pakistani Labeo, Indus Garua, Spiny Eel, Suckerhead, Kashmir Latia and Nalbant's Loach.

Figure D-12 shows photographs of some fish species reported from Zone J.

Discussion

Fish Diversity: A total of 38 fish species has been reported from this zone. River Poonch is rich in fish diversity as 38 fish species have been recorded from a stretch of about 100 km. The diversity is higher in the area where the River Poonch makes its confluence with Mangla Reservoir. This diversity is quite high for a river of this size as compared to other rivers of AJK. The reason is the topography and water temperature of the river Poonch. The Poonch flows gently in a vast and flat valley which provides numerous breeding grounds for the reproduction of fish. High temperature and gravely, rocky and the sandy river bed of the river Poonch not only promotes high river productivity but also enhances the breeding capacity of aquatic organisms and their subsequent survival. Thus, the fish diversity of the fish in this zone is rated high.

Economic Importance of Fish: The species included in the IUCN Red List are the Golden Mahseer, Alwan Snow Trout, Pakistani Labeo and Indus Garua which are also commercially important. The other commercially important species are Common Carp, Grass Carp, Butter Catfish, Chirruh Snow Trout, and Suckerhead. Some of these species such as Golden Mahseer, Alwan Snow Trout, Pakistani Labeo and Indus Garua have high commercial importance. So overall the economic importance of fish in this zone is High.

Conservation Importance of Fish Species: Six species, Kashmir Catfish (Critically Endangered), Golden Mahseer (Endangered), Alwan Snow Trout (Vulnerable), Common Carp (Vulnerable), Twin Banded Loach (Vulnerable) and Butter Catfish (Near Threatened) are included in the IUCN Red List. Two fish species which are restricted range and endemic to Jhelum-Poonch basin reported from this zone include Nalbant's Loach and Kashmir Catfish. There are five migratory species reported from this zone i.e., Golden Mahseer, Alwan Snow Trout, Pakistani Labeo, Indus Garua, Suckerhead. The conservation importance of the fish species in this zone can be rated as High.

Protected Area: The entire stretch of the Poonch River and its tributaries has been declared as Poonch River Mahseer National Park.

Figure D-12: Photographs of the Fish Species reported from Zone J

a) Pakistani *Labeo dyocheilus*

b) Butter Catfish *Ompok bimaculatus*

c) Kashmir Catfish *Glyptothorax kashmerensis*

d) Golden Mahseer *Tor putitora*

ANNEX D.A: FISH SPECIES OF JHELUM-POONCH BASIN

No.	Scientific Name	Common Name	IUCN Status	Year Published	Endemism	Migratory	Zone
1	*Acanthocobitis botia*	Mottled Loach	Least Concern	2009			Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
2	*Ambassis nama*	Elongate Glassy Perchlet	Not Assessed				Jhelum River (H) and Poonch River (J)
3	*Aspidoparia morar*	Aspidoparia	Least Concern	2010			Jhelum River (H) and Poonch River (J)
4	*Barilius pakistanicus*	Pakistani Baril	Not Assessed				Jhelum River (H) Mahl River (I) and Poonch River (J)
5	*Barilius vagra*	Vagra Baril	Least Concern	2010			Jhelum River (H) and Poonch River (J)
6	*Botia birdi*	Birdi Loach	Not Assessed				Jhelum River (G, H), Mahl River (I) and Poonch River (J)
7	*Botia lohachata*	Reticulate Loach	Not Assessed				Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
8	*Botia rostrata*	Twin banded Loach	Vulnerable	2010			Jhelum River (H), Mahl River (I) and Poonch River (J)
9	*Channa gachua*	Dwarf Snakehead	Least Concern	2010			Mahl River (I) and Poonch River (J)
10	*Cirrhinus reba*	Reba Carp	Least Concern	2011			Jhelum River (G, H) and Poonch River (J)
11	*Clupisoma garua*	Indus Garua	Least Concern	2010		✓	Jhelum River (E, F, G, H) and Poonch River (J)
12	*Crossocheilus diplochilus*	Kashmir Latia	Not Assessed				Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
13	*Ctenopharyngodon idella*	Grass Carp	Not Assessed				Jhelum River (H) and Poonch River (J)
14	*Cyprinus carpio*	Common Carp	Vulnerable	2008			Jhelum River (F, H) and Poonch River (J)
15	*Diptychus maculatus*	Tibetan Snow Trout	Not Assessed				Neelum River (C)
16	*Gagata cenia*	Clown Catfish	Least Concern	2010			Jhelum River (H) and Poonch River (J)
17	*Garra gotyla*	Suckerhead	Least Concern	2010		✓	Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
18	*Glyptosternum reticulatum*	Himalayan Catfish	Not Assessed				Kunhar River (A, B), Neelum River (C, D), and Mahl River (I)
19	*Glyptothorax cavia*	Cave Catfish	Least Concern	2010			Poonch River (J)
20	*Glyptothorax kashmirensis*	Kashmir Catfish	Critically Endangered	2010	✓		Jhelum River (E, F, G), and Poonch River (J)
21	*Glyptothorax naziri*	Naziri Catfish	Not Assessed				Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)

No.	Scientific Name	Common Name	IUCN Status	Year Published	Endemism	Migratory	Zone
22	*Glyptothorax pectinopterus*	Flat Head Catfish	Least Concern	2010			Kunhar River (B), Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
23	*Glyptothorax punjabensis*	Punjab Catfish	Not Assessed				Jhelum River (H) and Poonch River (J)
24	*Glyptothorax stocki*	Bhed Catfish	Not Assessed				Jhelum River (E, F, G), and Poonch River (J)
25	*Glyptothorax telchitta*	Sutlej Catfish	Least Concern	2010			Poonch River (J)
26	*Hypophthalmichthys molitrix*	Silver Carp	Near Threatened	2011			Jhelum River (H) and Poonch River (J)
27	*Labeo dyocheilus*	Pakistani Labeo	Least Concern	2010		✓	Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
28	*Mastacembelus armatus*	Spiny Eel	Least Concern	2010			Jhelum River (H), Mahl River (I) and Poonch River (J)
29	*Ompok bimaculatus*	Butter Catfish	Near Threatened	2010			Poonch River (J)
30	*Oncorhynchus mykiss*	Rainbow Trout	Not Assessed				Kunhar River (A, B), and Neelum River (C)
31	*Osteobrama cotio*	Cotio	Least Concern	2010			Jhelum River (H)
32	*Parambassis baculis*	Himalayan Glassy Perchlet	Least Concern	2010			Jhelum River (H) and Poonch River (J)
33	*Parambassis ranga*	Indian Glassy Fish	Least Concern	2012			Jhelum River (H) and Poonch River (J)
34	*Puntius chola*	Chola Barb	Least Concern	2010			Jhelum River (H) and Poonch River (J)
35	*Puntius sophore*	Spotfin Swamp Barb	Least Concern	2010			Jhelum River (H) and Poonch River (J)
36	*Puntius ticto*	Two Spot Barb	Least Concern	2015			Jhelum River (H) and Poonch River (J)
37	*Salmo trutta fario*	Brown Trout	Not Assessed				Kunhar River (A), Neelum River (C, D)
38	*Schistura afasciata*	Havelian Loach	Not Assessed				Jhelum River (E, F, G)
39	*Salmophasia bacaila*	Large Razorbelly Minnow	Least Concern	2011			Jhelum River (H) and Poonch River (J)
40	*Schistura alepidota*	Stone Loach	Not Assessed				Kunhar River (B), Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
41	*Schistura arifi*	Arif's Loach	Not Assessed				Kunhar River (B), Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
42	*Schistura nalbanti*	Nalbant's Loach	Not Assessed		✓		Kunhar River (B), Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
43	*Schistura punjabensis*	Punjab Loach	Not Assessed				Jhelum River (H), Mahl River (I) and Poonch River (J)

No.	Scientific Name	Common Name	IUCN Status	Year Published	Endemism	Migratory	Zone
44	*Schizopyge esocinus*	Chirruh Snowtrout	Not Assessed				Jhelum River (E, F, G), and Poonch River (J)
45	*Schizothorax macropogon*		Not Assessed				Neelum River (D), Jhelum River (E, G)
46	*Schizothorax curvifrons*	Sattar's Snow Trout	Not Assessed				Jhelum River (E, F, G)
47	*Schizothorax labiatus*	Kunar Snow Trout	Not Assessed				Kunhar River (B), Neelum River (D), and Jhelum River (E, F, G)
48	*Schizothorax richardsonii*	Alwan Snow Trout	Vulnerable	2010		✓	Kunhar River (A, B), Neelum River (C, D), Jhelum River (E, F, G, H), Mahl River (I) and Poonch River (J)
49	*Securicula gora*	Gora Chela	Least Concern	2010			Jhelum River (E, F, G, H), and Poonch River (J)
50	*Tor putitora*	Mahseer	Endangered	2010		✓	Jhelum River (G, H), Mahl River (I) and Poonch River (J)
51	*Triplophysa kashmirensis*	Kashmir Hill Stream Loach	Not Assessed		✓		Kunhar River (A, B) and Neelum River (C, D)
52	*Triplophysa microps*	Leh Triplophysa Loach	Least Concern	2010			Neelum River (C, D), and Jhelum River (E)
53	*Triplophysa stoliczkai*	Tibetan Stone Loach	Not Assessed				Neelum River (C, D)
54	*Xenentodon cancila*	Freshwater Garfish	Least Concern	2010			Jhelum River (H) and Poonch River (J)

Annex E

Socio-economic Conditions of Zones

The section describes the socio-economic condition of zones in Area of Management. Background information on the overall socio-economic setting at the state and district levels is included under Annex E.A, *Socio-economic Profile of Area of Management*, at the end of **Annex E**.

E.1 Socio-economic Zones in Area of Management

The Area of Management can be delineated into the following zones keeping in view similarities in socio-economic conditions. These zones are shown in **Figure E-1**.

- Zone A - Kunhar River (Lulusar Lake to Paras Town)
- Zone B - Kunhar River (Paras Town to Muzaffarabad)
- Zone C - Neelum River (Taobat to Dudhnial)
- Zone D - Neelum River (Dudhnial to Muzaffarabad)
- Zone E - Jhelum River (Chakothi to Muzaffarabad)
- Zone F - Muzaffarabad: (Muzaffarabad City)
- Zone G - Jhelum River (Downstream Muzaffarabad to confluence of Mahl River)
- Zone H - Jhelum River (Confluence of Mahl River to Mangla Reservoir)
- Zone I - Mahl River (Mahl River from Nar Sher Khan to confluence of Jhelum River)
- Zone J - Poonch River (Entire stretch of Poonch River and tributaries within Line of Control to Mangla Reservoir)

The Mangla Reservoir is not a natural waterbody and has been excluded from the Area of Management.

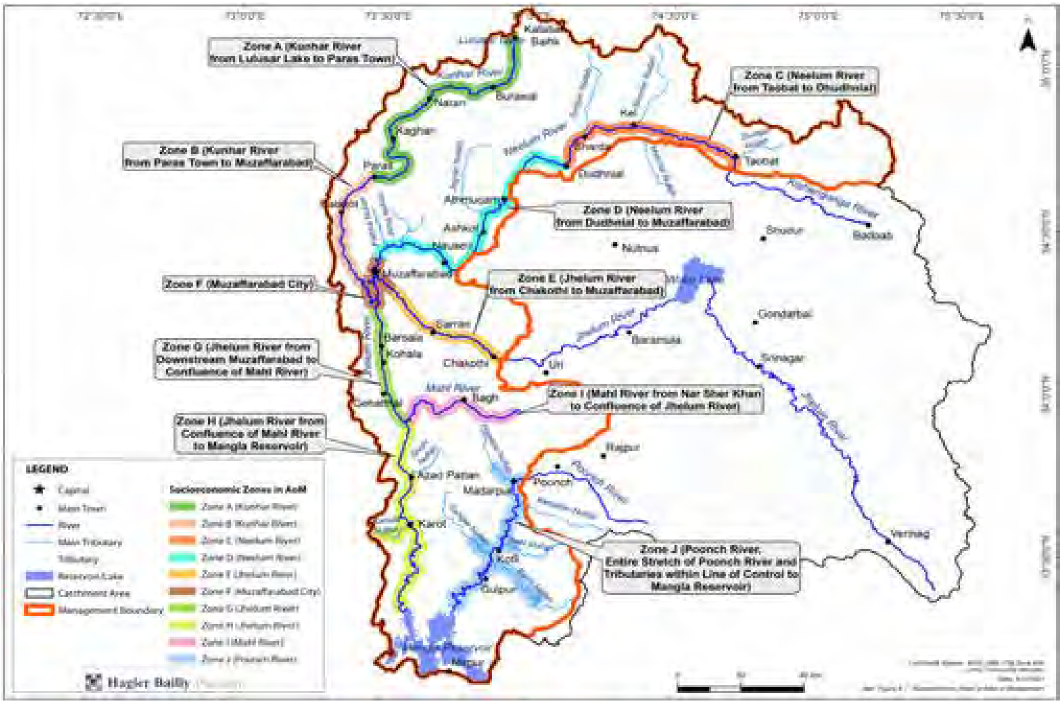
E.2 Socio-economic Conditions in Zones

This section provides a brief description of the socio-economic conditions in the zones of the Area of Management. Uses and dependence of the local communities on the river and river resources including sediments[1], fish and river water is also outlined.

E.2.1 Zone A: Kunhar River (Lulusar Lake to Paras Town)

Zone A is mainly rural with some urban areas like Kaghan and Naran. It falls within the jurisdiction of the Mansehra District and Abbottabad District. Agricultural patches can be observed in this zone which are sustained by rainfall and water provided by irrigation channels from mountain streams however, irrigation is not carried out through river water. Most of the settlements are close to the national highway N–15 and linked through unsealed roads. N–15

Figure E-1: Socioeconomic Zones in Area of Management



[1] Statistics provided in this section do not include small-scale mining operations. Small-scale mining operation is not mechanized, and extraction is done by one-or two-persons using shovels and spades. Mined sediment is transported with the help of animals.

from Lulusar Lake to Kaghan town remains closed from November to April due to snowfall in the area. Electricity and communication services are available in almost all the settlements.

Sediment Mining

Sediment (sand, gravel and cobble) mining is mainly carried out in the last part (from Kaghan to Paras) of this zone. The mineable sediment resource is being extracted to meet small-scale construction demand, involving construction and maintenance of local residential and commercial buildings.

The mining techniques are crude, involving the use of labor for dredging. Mechanical extraction is limited. The sand and gravel are mined using shovels and spades and are loaded onto animals and vehicles, from where it is transported to the roadside. The unit used for measurement of sand is locally called "Secra" and one Secra is equal to 100 square feet. Photographs of mining activities from this zone are shown in **Figure E-2**.

Table E-1 summarizes the estimates for sediment mined along the main Kunhar River in the Area of Management.

Fishing

Fishing for self-consumption has been observed in Zone A. As reported by the fishermen almost 100% of the fish is self-consumed. Fisheries Department, Khyber Pakhtunkhwa (KP) issues permits to the fishermen for fishing and some fishermen get permits after paying tax however most of the fishing is carried out illegally, i.e., without obtaining permits from the Fisheries Department, KP. Therefore, fishermen are reluctant to share information on the fishing activities and volume of fish caught.

Table E-2 provides basic statistics about fishing in the zone.

Figure E-2: Sand Mining Methods

Mined sand stored along the road

Sand mining along Rajalwal settlement

Table E-1: Sand Mining Statistics in Zone A

Indicators	Quantity
River stretch (km)	103.4
Estimated number of mining businesses (Nos)	31
Volume extracted annually per business (m^3)	1,882
Total extracted annually in the zone (m^3)	58,327
Sand mined m^3 per km stretch of river	564
Estimated number of persons involved	92
Estimate value (million PKR)	31
Total annual income per business (million PKR)	1.0

Table E-2: Fishing Statistics in Zone A

Indicators	Quantity
Number of fishermen	95
Total fish catch per year (Kg)	6180
River stretch (km)	103.4
Average fish catch per year per capita (kg)	65.05
Fish catch per km stretch of river (kg)	59.77
Self–consumed	100%
Estimated total income from fishing (PKR)	0
Average annual income from fishing per fisherman (PKR)	0.00

Tourism Potential

This zone is popular with tourists but hosts tourists only during the summer season because of the temperatures in winter drop below freezing point. In winter this area becomes inaccessible for outsiders. Kaghan, Naran, Lulusar Lake, Lalazar, Lake Saiful Muluk, Lake Dudipatsar, Aansoo (Tear drop) Lake, and Babusar Top are important places for tourists in this zone.

E.2.2 Zone B: Kunhar River (Paras Town to Muzaffarabad)

This Zone is mainly rural with some urban areas around Balakot city. This zone falls within the jurisdiction of the Abbottabad District and Muzaffarabad District. The main sources of income in this zone are jobs (52%), labor (19%) and business (17%). Villages with agricultural areas along the banks of the river are common and almost 48% of households have agricultural lands with an average land holding of 5 Kanals. The average household size is 6.2. The literacy rate in the zone is 71%. Most of the settlements are close to the national highway N–15 and linked through unsealed roads. Electricity and communication services are available in almost all the settlements. Schools and health facilities (BHUs) are available within or along the settlements. Tehsil headquarter hospital is available in Balakot. The source of drinking water in most of the settlements is water springs. Communities have installed pipes to bring water to their houses. Services like hospitals, police stations, market and banks are available at tehsil headquarter Balakot.

Sediment Mining

Sediment (sand, gravel and cobble) mining is carried out throughout the zone. The mineable sediment resource is being extracted to meet small-scale construction demand, involving construction and maintenance of local residential and commercial buildings as well as for roads. According to information provided by miners in the Balakot area, the import of sediment varies from year-to-year depending on the status of the construction industry.

The mining techniques are crude, involving the use of labor for dredging. Mechanical extraction is limited. The sand and gravel are mined using shovels and spades and are loaded onto animals and vehicles, from where it is transported to the roadside. The unit used for measurement of sand is locally called “Secra” and one Secra is equal to 100 square feet. Photographs of mining activities from this zone are shown in **Figure E-3**.

Figure E-3: Sand Mining Methods[2]

Sand transportation by Jeep

Transporting sand and gravel using tractor trolleys

Sand Mining Trough at Bararkot

Sand mining with excavator

[2] Hagler Bailly Pakistan (HBP), 2017. *Environment and Social Impact Assessment of Balakot Hydropower Project*. Report prepared for Asian Development Bank (ADB).

Table E-3 summarizes the estimates for sediment mined along the main Kunhar River in the Area of Management.

Fishing

Fishing for self-consumption has been observed in Zone B. Fishing as a business has not been reported except in Balakot city. About 88% of the fish is self-consumed whereas the rest is sold commercially. As fishing is carried out illegally, i.e., without obtaining permits from the Fisheries Department, KP, fishermen are reluctant to share information on the fishing activities and volume of fish caught. Fishing activities are shown in **Figure E-4**.

Table E-4 provides basic statistics about fishing in the zone.

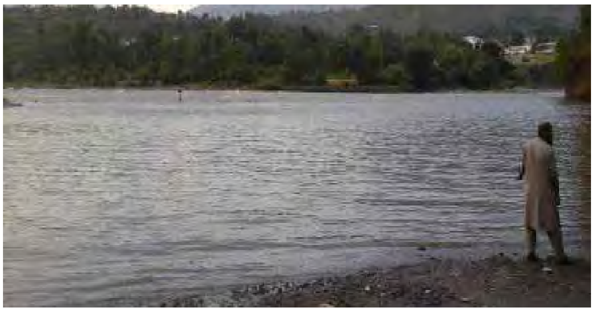
Table E-3: Sand Mining Statistics in Zone B

Indicators	Quantity
River stretch (km)	49.2
Estimated number of mining businesses (Nos)	286
Volume extracted annually per business (m^3)	2,460
Total extracted annually (m^3)	467,030
Sand mined m^3 per km stretch of river	9,492
Estimated number of persons involved	519
Estimate value (million PKR)	247.40
Total annual income per business (million PKR)	0.87

Table E-4: Fishing Statistics in Zone B

Indicators	Quantity
Number of fishermen	234
Total fish catch per year (kg)	3040
River stretch (km)	49.2
Average fish catch per year per capita (kg)	12.99
Fish catch per km stretch of river (kg)	61.79
Self–consumed	88%
Estimated total income from fishing (PKR)	437,760
Average annual income from fishing per fisherman (PKR)	1,871

Figure E-4: Photographs of Fishing Activities in Zone B[3]



Gill Netting downstream of Bissian

Cast Netting upstream of Bissian

Fishing with Rod at Talhatta

Fishing at Karnol

[3] Hagler Bailly Pakistan (HBP). 2017. *Environmental and Social Impact Assessment (ESIA) of Balakot Hydropower Project*. Report prepared for ADB.

Tourism Potential

Zone B is important for tourism. People from other parts of the country visit Balakot, Shogran and Paras. In summer, people visiting the Naran valley also stay in this zone. Other than Shogran and Paras, there are several points along the river which are popular with tourists, particularly at the confluence of streams and tributaries with the Kunhar River.

E.2.3 Zone C: Neelum River (Taobat to Dhudhnial)

Zone C is entirely rural and falls within the jurisdiction of the Neelum District. Villages with agricultural areas along the banks of the river are common. The villages are mainly located on the right bank, which has low topographic relief, while there is a thick cover of mixed conifer and deciduous trees on the steeper left bank. Agriculture forms the main occupation in this zone and is based on rainfall and water provided by irrigation channels that are fed by tributaries or side streams. Seasonal migration to urban areas downstream for employment is common.

Sediment Mining

Sand and gravel mining are not very common in this zone. **Table E-5** summarizes the estimates for sediment mined in the Study Zone.

Fishing

Brown Trout, commonly found in this zone, is important commercially and for sport fishing. Alwan Snow Trout and Tibetan Snow Trout are locally consumed as food fish. **Table E-6** provides fishing statistics in Zone C.

Tourism Potential

The zone hosts tourists in the summer season only, because the temperatures in winter drop below freezing point. Tourist accommodation is available at Kel, Sharda and Keran. Linkages of the people's livelihoods to the Neelum River in the winter season are limited to river-based tourism and related activities, such as sport fishing.

E.2.4 Zone D: Neelum River (Dhudhnial to Muzaffarabad)

Like Zone C, Zone D is also entirely rural. This zone falls within the jurisdiction of the Neelum District and Muzaffarabad District. The sizes of the settlements are larger in this zone compared to Zone C. People serve as laborers and government servants. Seasonal migration for employment is negligible.

Sediment Mining

Sand and gravel mining are not very common in this zone. **Table E-7** summarizes the estimates for sediment mined in this zone.

Fishing

Brown Trout though has high commercial value but has a low abundance in this zone and is only seen in the winter months. Alwan Snow Trout is locally consumed as food fish. **Table E-8** provides fishing statistics for Zone D.

Tourism Potential

Zone D has low importance in terms of winter tourism potential relative to Zone C.

Table E-5: Sand Mining Statistics in Zone C

Indicators	Quantity
River stretch (km)	79.3
Estimated number of mining businesses (Nos)	23
Volume extracted annually per business (m³)	1,045
Total extracted annually (m³)	24,030
Sand mined m³ per km stretch of river	303.02
Estimated number of persons involved	97
Estimate value (million PKR)	12.73
Total annual income per business (million PKR)	0.55

Table E-6: Fishing Statistics in Zone C

Indicators	Quantity
Number of fishermen	314
Total fish catch per year (kg)	35,280
River stretch (km)	79.3
Average fish catch per year per capita (kg)	112
Fish catch per km stretch of river (kg)	445
Self–consumed	40%
Estimated total income from fishing (PKR)	25,401,600
Average annual income from fishing per fisherman (PKR)	80,897

Table E-7: Sand Mining Statistics in Zone D

Indicators	Quantity
River stretch (km)	102.8
Estimated number of mining businesses (Nos)	20
Volume extracted annually per business (m^3)	596
Total extracted annually (m^3)	11,916
Sand mined m^3 per km stretch of river	116
Estimated number of persons involved	338
Estimate value (million PKR)	6.31
Total annual income per business (million PKR)	0.32

Table E-8: Fishing Statistics in Zone D

Indicators	Quantity
Number of fishermen	57
Total fish catch per year (kg)	7,500
River stretch (km)	102.8
Average fish catch per year per capita (kg)	132
Fish catch per km stretch of river (kg)	73
Self–consumed	47%
Estimated total income from fishing (PKR)	3,180,000
Average annual income from fishing per fisherman (PKR)	55,789

Table E-9: Sand Mining Statistics in Zone E

Indicators	Quantity
River Stretch (km)	50.2
Estimated Number of Mining Businesses	64
Volume extracted annually per business (m^3)	4,591
Total extracted annually (m^3)	293,821
Sand mined m^3 per km stretch of river	5,853
Estimated Number of Persons Involved	77
Estimate value (million PKR)	207.52
Total annual income per business (million PKR)	3.24

Table E-10: Fishing Statistics in Zone E

Indicators	Quantity
Number of fishermen	126
Total fish catch per year (kg)	7,290
River stretch (km)	50.2
Average fish catch per year per capita (kg)	58
Fish catch per km stretch of river (kg)	145
Self–consumed	80%
Estimated total income from fishing (PKR)	1,166,400
Average annual income from fishing per fisherman (PKR)	9,257

E.2.5 Zone E: Jhelum River (Chakothi to Muzaffarabad)

River Jhelum enters Azad Jammu and Kashmir near the town of Chakothi. This zone falls within the jurisdiction of Chakothi Hattian District and Muzaffarabad District. Livelihood sources include sand and gravel mining, fishing, running hotels and restaurants. There are different methods of sand gravel mining and this provides livelihood opportunities for people associated with this business.

Sediment Mining

Sand and gravel mining have been reported from this zone. Simple machines or bucket like devices operated by a lever is used to extract the sediment. **Table E-9** summarizes the estimates for sediment mining in this zone. Photographs of mining activities are shown in **Figure E-5**.

Fishing

Fishing is not very common in this zone. **Table E-10** provides fishing statistics in Zone E.

Tourism potential

Zone E has low importance for tourism though there are a few restaurants along the Jhelum River where tourists stop for food and hotels that provide accommodation for tourists.

Figure E-5: Photographs of Sand Mining in Zone E[4]

Sand transport by Truck

Extracting sand gravel using tractor trolleys, Mazda, four-wheel Jeeps and other vehicles

Bella (Sand gravel deposition in Langarpura Bella)

Extracting sand gravel through horses, mules and donkeys

E.2.6 Zone F: Muzaffarabad: (Muzaffarabad City)

Zone F includes Muzaffarabad and surrounding semi-rural settlements. This zone falls within the jurisdiction of Muzaffarabad District. Muzaffarabad is the capital of Azad Jammu and Kashmir (AJK) and headquarter of District Muzaffarabad. It is also the economic hub of the AJK. The city is situated at the confluence of the Jhelum and Neelum rivers. Photographs of Muzaffarabad city and surroundings are shown in **Figure E-6.**

Sediment Mining

The sand and gravel extracted from sub urban areas are utilized for construction in Muzaffarabad. However, there are alternate supply areas for Muzaffarabad in the Neelum Valley, where sand and gravel are mined in quarries along the road. **Table E-11** summarizes the estimates for sediment mined in this zone.

Figure E-6: Photographs of Muzaffarabad city and surroundings (Zone F)[5]

Muzaffarabad city

Quarry in Kamsar supplying sand and gravel to Muzaffarabad

[4] Hagler Bailly Pakistan (HBP), 2017. *Environmental and Social Impact Assessment (ESIA) Report of the 1,124 MW Kohala Hydropower Project*. Report prepared for Kohala Power Company (Pvt.) Limited.

[5] Hagler Bailly Pakistan (HBP), 2017. *Environmental and Social Impact Assessment (ESIA) Report of the 1,124 MW Kohala Hydropower Project*. Report prepared for Kohala Power Company (Pvt.) Limited.

Table E-11: Sand Mining Statistics in Zone F

Indicators	Quantity
River Stretch (km)	51.5
Estimated Number of Mining Businesses	129
Volume extracted annually per business (m^3)	3625
Total extracted annually (m^3)	467,625
Sand mined m^3 per km stretch of river	9,080
Estimated Number of Persons Involved	136
Estimate value (million PKR)	330.28
Total annual income per business (million PKR)	2.56

Table E-12: Fishing Statistics in Zone F

Indicators	Quantity
Number of fishermen	12
Total fish catch per year (kg)	846
River stretch (km)	51.5
Average fish catch per year per capita (kg)	71
Fish catch per km stretch of river (kg)	16
Self–consumed	80%
Estimated total income from fishing (PKR)	84,600
Average annual income from fishing per fisherman (PKR)	7,050

Table E-13: Sand Mining Statistics in Zone G

Indicators	Quantity
River Stretch (km)	45.6
Estimated Number of Mining Businesses	29
Volume Extracted Annually Per Business (m^3)	1,172
Total Extracted Annually in the Zone (m^3)	33,666
Sand mined m^3 per km stretch of river	738
Estimated Number of Persons Involved	34
Estimate value (million PKR)	23.78
Total annual income per business (million PKR)	0.82

Table E-14: Fishing Statistics in Zone G

Indicators	Quantity
Number of fishermen	12
Total fish catch per year (kg)	4,320
River stretch (km)	45.6
Average fish catch per year per capita (kg)	360
Fish catch per km stretch of river (kg)	94.74
Self–consumed	90%
Estimated total income from fishing (PKR)	216,000
Average annual income from fishing per fisherman (PKR)	18,000

Fishing

There is little fishing in this zone. The fish provided in restaurants in Muzaffarabad is largely from the Mangla Reservoir. A small proportion of fish caught from the Jhelum or Neelum rivers is transported to Muzaffarabad. **Table E-12** provides fishing statistics in Zone F.

Tourism potential

Zone F has low importance for tourism. However, tourists going to Neelum valley often stay in Muzaffarabad. There are few good food places along the river for the tourists.

E.2.7 Zone G: Jhelum River (Downstream Muzaffarabad to confluence of Mahl River)

Zone G extends from Muzaffarabad city to the confluence of Mahl River. On the left side of the river there are Muzaffarabad and Bagh Districts of AJK and on the right side of the Jhelum River are Abbottabad District of KP and Rawalpindi District of Punjab. All the settlements are rural settlements along Jhelum River in this Zone.

Sediment Mining

There is extensive sand mining along the entire stretch of Jhelum River, particularly south of the Kohala Bridge. **Table E-13** summarizes the estimates for sediment mined in this zone.

Fishing

As illustrated in **Table E-14**, a small proportion of households are involved in fishing activities in this zone. The common fish species caught include Mahseer, Alwan Snow Trout and Rahu. Cast nets, gill nets and rods are the main fishing equipment reported by the respondents. As can be seen from the figures in **Table E-14**, fishing is not an important source of livelihood in this zone.

Tourism potential

There is very little tourism in Zone G and recreational dependence on the river is low. There is a tourist point at Kohala Bridge where there are a few restaurants and food stalls. Tourists going upstream often stop here to have lunch.

E.2.8 Zone H: Jhelum River (Confluence of Mahl River to Mangla Reservoir)

This zone falls within the jurisdiction of Bagh District, Poonch District, Sudhnoti District and Mirpur District of AJK and Rawalpindi District of Punjab. Settlements in this zone are rural. On the whole, river dependent socio-economic activities in this zone were found to be quite limited.

Sediment Mining

Table E-15 gives estimates for sediment mining (sand, gravel and cobble) along the Jhelum River in Zone H from confluence of Mahl River to Mangla Reservoir. As can be seen in **Figure E-7**, sediment mining is carried out throughout this zone, but is most prevalent along Dhalkot, along the right bank of the river. The amount of sediment extracted per km stretch of the river is highest in this area.

The mineable sediment resource is being extracted to meet small-scale construction demand, involving construction and maintenance of local residential and commercial buildings as well as for roads. Miners in the area have reported that the import of sediment varies from year-to-year depending on the status of construction in the area.

Table E-15: Sand Mining Statistics in Zone H

Indicators	Quantity
River stretch (km)	90.4
Estimated number of mining businesses (Nos)	20
Volume extracted annually per business (m^3)	2,582
Total extracted annually in the zone (m^3)	51,632
Sand mined m^3 per km stretch of river	571
Estimated number of persons involved	155
Estimate value (million PKR)	27.35
Total annual income per business (million PKR)	1.37

Fishing

There is limited fishing activity in this zone. Some of the fish caught is consumed by the families engaged in fishing while the rest is sold locally on a small scale. The fishing season lasts approximately six months through the year, depending on the fish species caught. Seasonal permits for fishing using rods and cast nets are issued by the concerned fisheries departments. However, most of the fish caught, whether for self-consumption or for business, is caught without permits as law enforcement is very weak. The most common fish species caught include the Mahseer, Alwan Snow Trout and Pakistani Labeo. **Table E-16** provides fishing statistics for Zone H.

Tourism potential

There is very little tourism in Zone H and recreational dependence on the river is low.

Figure E-7: Sand Mining Methods in Zone H[6]

Sand Mining at Dhalkot

Sand Transportation at Dhalkot

[6] Hagler Bailly Pakistan (HBP), 2017. *Environment and Social Impact Assessment of Azad Pattan Hydropower Project*. Report prepared for Azad Pattan Power (Pvt.) Ltd.

Table E-16: Fishing Statistics in Zone H

Indicators	Quantity
Number of fishermen	12
Total fish catch per year (kg)	520
River stretch (km)	90.4
Average fish catch per year per capita (kg)	43
Fish catch per km stretch of river (kg)	5.75
Self–consumed	100%
Estimated total income from fishing (PKR)	–
Average annual income from fishing per fisherman (PKR)	–

E.2.9 Zone I: Mahl River (Mahl River from Nar Sher Khan to confluence of Jhelum River)

This zone is mainly rural with some urban areas around Bagh city. It falls within the jurisdiction of Bagh District. On the whole, river dependent socio-economic activities in this zone were found to be moderate. Details of sediment mining, fishing, recreation and tourism are given in the following sections.

Sediment Mining

Sediment mining has been reported throughout Zone I (**Table E-17**). The mined sediment is extracted to meet small-scale construction demand, involving construction, renovation of local residential and commercial buildings. The sediment mining is commonly undertaken all year round. However, due to the high-water volumes in the river between June to August, mining is limited in this season. Photographs of sediment mining in Zone I are presented in **Figure E-8**.

Table E-17: Sediment Mining Statistics in Zone I

Indicators	Quantity
River stretch (km)	110.8
Estimated number of mining businesses (Nos)	16
Volume extracted annually per business (m^3)	13,632
Total extracted annually in the zone (m^3)	218,112
Sediment mined m^3 per km stretch of river	1,969
Estimated number of persons involved	29
Estimate value (million PKR)	115.54
Total annual income per business (million PKR)	7.22

Figure E-8: Photographs of the Sediment Mining in Zone I[7]

Sand mining at Barsala

Sand mining at Kunal

Transportation of sand from source at Numromal

Transportation of gravel at Gala

[7] Hagler Bailly Pakistan (HBP), 2018. *Environment and Social Impact Assessment of the Mahl Hydropower Project*. Report prepared for Shanghai Investigation Design & Research Institute Co., Islamabad.

Fishing

In this zone, a small proportion of households are involved in fishing activities. Illegal fishing is carried out in this zone. The most common fish species caught include Mahseer, Alwan Snow Trout and Rahu. Cast nets, gill nets and rods are the main fishing equipment reported by the respondents. As can be seen from the figures in **Table E-18**, fishing is not an important source of livelihood in Zone I.

Table E-18: Fishing Statistics in Zone I

Indicators	Quantity
Number of fishermen	24
Total fish catch per year (kg)	6120
River stretch (km)	110.8
Average fish catch per year per capita (kg)	255
Fish catch per km stretch of river (kg)	55
Self–consumed	16.70%
Estimated total income from fishing (PKR)	2,548,980
Average annual income from fishing per fisherman (PKR)	106,208

Tourism potential

There are some locations which are important for tourists like Bagh and Nar Sher khan. However, overall, the tourism in this zone is limited.

E.2.10 Zone J: Poonch River (Entire stretch of Poonch River and Tributaries within Line of Control to Mangla Reservoir)

This zone comprises of rural and urban areas. Most of the area of this zone falls within the jurisdiction of Kotli District while the southern part falls in Mirpur District. On the whole, river dependent socio-economic activities in this zone were found to be significant. Details of sediment mining, fishing, recreation and tourism are given in the following sections.

Sediment Mining

Sediment mining was reported throughout the Zone J. The mined sediment was being extracted to meet small-scale construction demand, involving construction, renovation of local residential and commercial buildings. The intensity of sediment mining with the River stretch in Zone J is shown in **Table E-19**. it is observed that in last 2-3 years sediment mining has reduced in Zone J due to the reduction of available sediments.

Table E-19: Sand Mining Statistics in Zone J

Indicators	Quantity[8]
River stretch (km)	90
Estimated number of mining businesses (Nos)	82
Volume extracted annually per business (m^3)	19,308
Total extracted annually in the zone (m^3)	1,583,236
Sediment mined m^3 per km stretch of river	17,592
Estimated number of persons involved	703
Estimate value (million PKR)	1,007
Total annual income per business (million PKR)	12

Fishing

Fishing for domestic use is practiced in the entire zone. For fishing, AJK Fisheries and Wildlife Department provides licenses, however, most of the fishing is done illegally. **Table E-20** provides basic data regarding fishing in Zone J.

Table E-20: Fishing Statistics in Zone J

Indicators	Quantity
Number of fishermen	718
Total fish catch per year (kg)	61200
River stretch (km)	90
Average fish catch per year per capita (kg)	85
Fish catch per km stretch of river (kg)	680
Self–consumed	70.00%
Estimated total income from fishing (PKR)	6,426,000
Average annual income from fishing per fisherman (PKR)	8,950

Tourism Potential

Winter tourism has moderate potential in Poonch due to the warmer climate. People from Islamabad and other areas tend to visit Poonch in winters.

[8] Statistics updated based on field survey conducted by HBP for the development of Sustainable Sediment Mining and Management Plan for Poonch River Mahseer National Park from July 1, 2019 to July 28, 2019.

E.3
Women Dependence on River and River Resources

Information gathered for this assignment as well as the previous ESIAs conducted in the basin (**Section 1.7** in *Strategy for Sustainable Hydropower Development*) indicate that women dependence on the river is small. In a few settlements (less than 1% in Zone E, I, J) in the Jhelum-Poonch basin, women reported using the river water for meeting their household needs such as washing clothes and utensils, bathing, and collection of driftwood for fuel. Some women (less than 1%) reported that they use the river water for providing water to their livestock as well as bathing them. However, use of river water for domestic purposes is very limited.

Women living in villages near the river use the riverside for recreation and relaxation particularly during the summer months and during the holy month of Ramadhan. These women gather near the river where they sit together, socialize, and talk. This socialization is important for the psychological well-being of women.

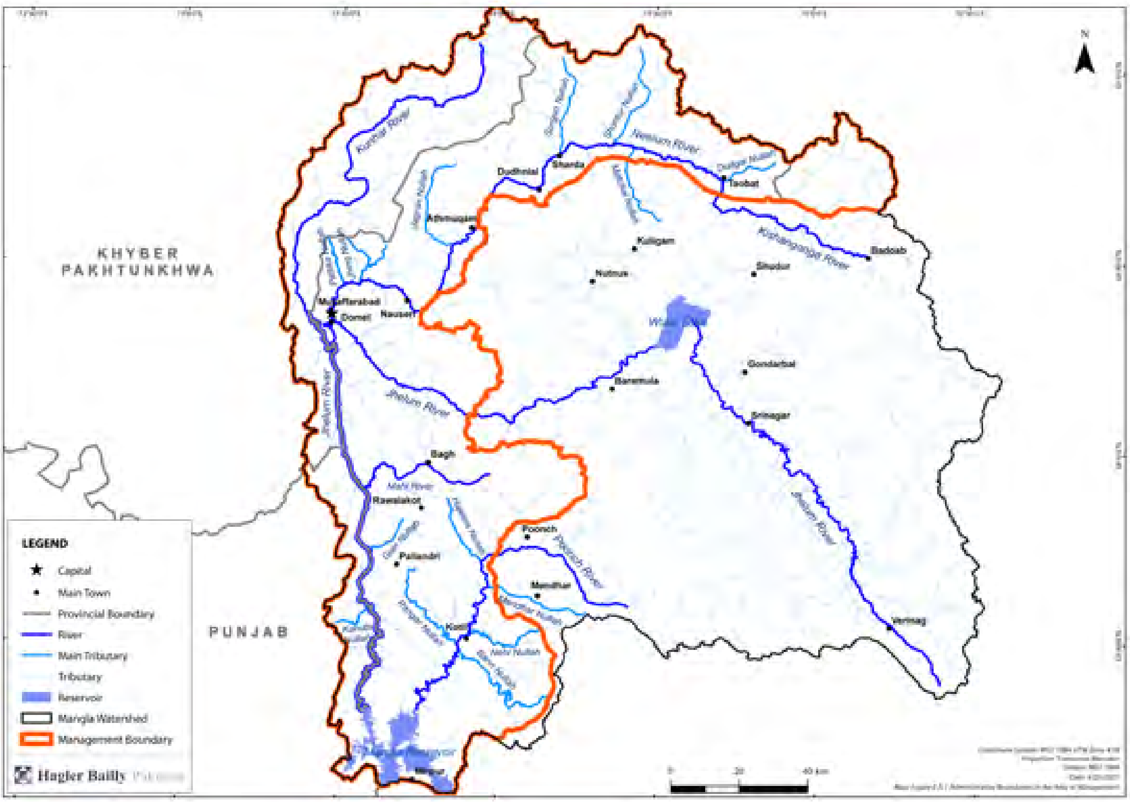
ANNEX E.A: SOCIO-ECONOMIC PROFILE OF AREA OF MANAGEMENT

This section provides an overview of the socio-economic conditions in the Area of Management (AoM) at the state and district level. The AoM includes the state of Azad Jammu and Kashmir (AJK), three districts of Khyber Pakhtunkhwa (KP) and one district of Punjab. **Figure E.A.1** shows the administrative boundaries in the AoM.

E.A.1
Socioeconomic Profile of AJK

AJK is an independent political entity within Pakistan. It has its own parliamentary government headed by the President. Administratively, AJK is divided into three divisions and 10 districts with Muzaffarabad

Figure E.A.1: Administrative Boundaries in the Area of Management



9 Azad Jammu & Kashmir at a Glance 2019, Planning and Development Department, Government of AJK https://pndajk.gov.pk/uploadfiles/downloads/AJK%20at%20a%20Glance%202019.pdf, Accessed on March 12, 2020.

10 Ibid

city as the capital of the state.

The topography of AJK is dominated by hilly and mountainous terrain with the districts of Neelum, Muzaffarabad, Bagh, Sudhnoti and Poonch located at the foothills of the Himalayas. Main rivers running through the state include the Neelum, Jhelum and Poonch rivers. According to the latest population census carried out in 2017, the population of Azad Jammu & Kashmir is over 4.05 million with an annual growth rate of 1.64, compared to 1998 when the population was 2.9 million.[9] Only 17% of the population resides in urban centers whereas the rest is rural. The population density is 304 persons per square kilometer.

E.A.1.1
Muzaffarabad District

Muzaffarabad District consists of Muzaffarabad city, the capital of AJK, and suburban areas located at the confluence of Jhelum and Neelum rivers. The population of Muzaffarabad District constitutes 0.662 million[10] which is 16% of the population of AJK, making it one of the densely populated districts.

Muzaffarabad is also the main trade center of AJK. Due to the topography of the area, it is not possible to establish large industrial units. However, the cottage industry thrives in the area - mainly carpet weaving, furniture making, wood carving, garment making and embroidery work. There are a few textile centers which produce bed sheets and coarse cloth.

E.A.1.2
Neelum District

Until 2005 Neelum District was part of Muzaffarabad district. With an area of 3,621 square kilometers, it is the largest district of AJK. The population of Neelum District constitutes only 4% of the population of AJK making it one of the sparsely populated districts. Population of Neelum District is 0.195 million.[11] More than 80% of the population of Neelum District resides within 3 km of the river,[12] mainly because traditional access routes in the Neelum Valley are located closer to the river, typical in valleys with steep slopes. The shape of the valley also affects the population distribution: where the valley is narrow, population is relatively low and where it is wide, it is relatively high. Seasonal migration in the summer to access the alpine grazing grounds at higher elevations in the valley and in winter to urban areas downstream for employment is common. However, higher migration levels can be observed in Sharda Tehsil and some union councils of Athmuqam Tehsil.

E.A.1.3
Bagh District

The Bagh District, which had been part of Poonch District, was created in 1988. The district is bounded by Muzaffarabad district to the north, Poonch district to the south, and Poonch district of the Indian-administered Jammu and Kashmir to the east. It is bound by Rawalpindi District, Punjab, and Abbottabad District, KP to the west. The total area of the district is 770 square kilometers and the population is 0.378 million.[13]

E.A.1.4
Jhelum Valley District

Jhelum Valley district was a part of Muzaffarabad district till announced as a district in July 2009. Baramula district of the Indian Administered Kashmir is located in the east, Kupwara district in the same territory is in the northeast, Neelum district of AJK is in the northwest, Muzaffarabad district is in the west and Bagh district is in the south of Hattian Bala district.

Total population of Jhelum Valley District is 0.235 million,[14] with rural–urban ratio of 90:10. The majority of the rural population depends on agriculture, livestock and forestry for its subsistence. Many people are working or settled abroad in the Middle East, the United Kingdom and the United States to support their families. Hattian Bala is mainly a hilly and mountainous region with stretches of plains along the riverside.

E.A.1.5
Poonch District

Poonch District is administratively divided into four tehsils namely Rawalakot, Hajira, Thorar, Abbaspur. Area wise, the district is one of the smaller districts in AJK. However, the population density of the district is 670 persons per square kilometer, the highest in AJK

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[11] Ibid

[12] Hagler Bailly Pakistan (HBP) 2011, Water Matters, Southern Waters, Environmental Assessment of Neelum River Water Diversion, Ministry of Water and Power, Islamabad.

[13] Azad Jammu & Kashmir at a Glance 2019, Planning and Development Department, Government of AJK https://pndajk.gov.pk/uploadfiles/downloads/AJK%20at%20a%20Glance%202019.pdf, Accessed on March 12, 2020.

[14] Ibid

[15] Ibid

[16] Ibid

with total population of 0.505 million.[15] The reason for high population density is the mountainous terrain. Means of livelihood in Poonch District include farming, livestock, poultry, government service (both civil and military), business and overseas employment. The contribution of the industry for supporting livelihoods is minimal. In-country seasonal migration for employment is very common.

E.A.1.6
Sudhnoti District

Sudhnoti District is the smallest of all the districts in AJK in terms of area and is home to only seven percent of AJK's population which is 0.303 million.[16] Administratively the district is divided into four tehsils, Pallandri, Mang, Baloch and Trarkhal. Pallandri is the district headquarters.

Roads are the main mode of transportation in the district. The total metaled road network in the district is 504 km. Transport facilities are available in the form of passenger vans, taxis, jeeps and buses. The district does not have the facility of a general post office (GPO) but 34 extra departmental branches of post offices exist. There are 14 telephone exchanges in the district.

E.A.1.7
Kotli District

Kotli District is the second largest district in AJK area-wise, and the largest in terms of population. It is divided in four subdivisions, Kotli, Fatehpur Thakiala, Sehnsa and Charhoi. Kotli, the districts headquarter is located at a distance of 114 km from Rawalpindi/ Islamabad. Total population of the Kotli District is 0.787 million persons.[17]

Roads are the main mode of transportation in the district. Total metaled road network in the district is 1,014 km. Transport facilities such as passenger vans, taxis, jeeps and buses are used for traveling within the district and other districts.

E.A.1.8
Mirpur District

Mirpur District comprises of 11% of the total population of AJK which is 0.464 million. It is administratively divided in three tehsils, Mirpur, Dudyal and Chakswari. Mirpur, the district headquarter is situated at an elevation of 459 m above sea level. It is linked with the main Peshawar-Karachi Grand Trunk road at Deena, a small town about 15 km short of Jhelum city. The district comprises of both mountainous terrain and plains. The people of the area are mainly associated with agriculture. A number of individuals from this district migrated to the United Kingdom in the 1960s to work as laborers after construction of the Mangla Dam flooded agricultural fields. The government of AJK has successfully endeavored to develop the district as an industrial place and promote private investment for establishing textile, vegetable, ghee, garments, scooters, cosmetics and many other industries. Mirpur city is well planned, and buildings are of modem design. It has rapidly developed into an industrial city. All the basic amenities of life such as colleges, hospitals, banks, shopping centers, hotels, hostels, telephone; and telegraph units are available here.

E.A.2
Socio-economic Profile of Khyber Pakhtunkhwa

Khyber Pakhtunkhwa (KP) is one of the four administrative provinces of Pakistan located in the northwestern region of the country. It was previously known as the North West Frontier Province (NWFP) until 2010. Khyber Pakhtunkhwa is the third largest province of Pakistan by the size of both its population and economy. It comprises 10.5% of Pakistan's economy, and is home to 11.9% of Pakistan's total population. KP has a total of 7 Divisions, 25 Districts and 71 Tehsils.

Khyber Pakhtunkhwa has an estimated population of about 30,523,371, according to PBS 2017 estimates.[18] The largest ethnic group is the Pashtun, who historically have been living in the areas for centuries. Around 1.5 million Afghan refugees also remain in the province, the majority of whom are Pashtuns followed by Tajiks, Hazaras, and other smaller groups. **Table E.A.1** shows demographic statistics of KP.

Table E.A.1: Demographic Statistics of KP

Detail Population of KP Census 2017	Urban	Rural	Total
Population	5,729,634	24,793,737	30,523,371
Male	2,972,367	12,495,278	15,467,645
Female	2,756,577	12,298,236	15,054,813
Transgender	690	223	913
Household	741,014	3,104,154	3,845,168

[17] Ibid

[18] Pakistan Bureau of Statistics (PBS), Provisional Results of Census, 2017, Available at: http://www.pbs.gov.pk/sites/default/files/PAKISTAN%20TEHSIL%20WISE%20FOR%20WEB%20CENSUS_2017.pdf. Accessed on March 12, 2020.

[19] Ibid

E.A.2.1
Mansehra District

Mansehra district and town are named after Man Singh, a leading general of Mughal Emperor Akbar. The district is considered as an important tourist location due to the Kaghan Valley being located in the district, and the Karakoram Highway (KKH) passing through it. It was established as a district in 1976, prior to which it was a tehsil within the former Hazara District.

The total population for the Mansehra, Balakot and Oghi tehsils counted in the 2017 census was 1,556,460 individuals.[19] The predominant language in the district is Hindko followed by Pashto. There are also speakers of the widely dispersed Gujari language, particularly in the Kaghan Valley. There is also a small community in the village of Dani in Oghi Tehsil who speaks the endangered Mankiyali language.

E.A.2.2
Abbottabad District

Abbottabad is bordered by Mansehra district in the North, Muzaffarabad district in the East, Rawalpindi district in the South and the Haripur district in the West. The district covers an area of 1,969 km², with the city of Abbottabad being the principal town. According to the population census of 2017,[20] the total population of District Abbottabad is 1,332,912 which includes 677,570 males, 655,281 females and 60 transgenders. Average annual population growth rate is 2.20 observed from 1998 to 2017. According to the old Hazara gazetteers the main tribes here are the Karlal (Sardar), Turks, Dhund, Tanolis, Tareens, Awans, Sulemankhel, Jadoons, Qureshi, Mughals, Gujjars, Syeds and Sattis.

The major language of the area is Hindko, which in the 1981 census was the mother tongue of 95% of households. In the Galiyat Region in the southeast of the district, the language is still known as Hindko but becomes more different and gradually transitions into the core dialects of Paharii.

E.A.3
Socioeconomic Profile of Punjab

Punjab is Pakistan's second largest province by area and is the most populous province. Total area of the province is 205,344 km² with an estimated population of 110,012,442 as of 2017[21] with 64% urban population and 36% rural population. It is bordered by the Pakistan provinces of Sindh, Baluchistan and Khyber Pakhtunkhwa, the enclave of Islamabad and AJK. The Provincial capital of Punjab is the city of Lahore, a cultural, historical, economic and cosmopolitan center of Pakistan. Administratively, Punjab is divided into nine divisions and 36 districts. **Table E.A.2** shows demographic statistics of Punjab.

Table E.A.2: Demographic Statistics of Punjab

Detail Population of Punjab Census 2017	Urban	Rural	Total
Population	40,387,298	69,625,144	110,012,442
Male	20,760,984	35,197,990	55,958,974
Female	19,621,729	34,425,030	54,046,759
Transgender	4,585	2,124	6,709
Household	6,389,733	10,714,102	17,103,835

E.A.3.1
Rawalpindi District

Rawalpindi district is the only district of Punjab included in the Area of Management. It is located in the northernmost part of the Punjab province of Pakistan. The district has an area of 5,286 km². Originally, its area was 6,192 km² until the 1960s when Islamabad Capital Territory was carved out of the district, giving away an area of 906 km². Total population of the district is 5,405,633[22] individuals. It is situated on the southern slopes of the north-western extremities of the Himalayas, including large mountain tracts with rich valleys traversed by mountain rivers. The chief rivers are the Indus and Jhelum, and it is noted for its milder climate and abundant rainfall due to its proximity to the Margallah Hills.

[20] Ibid
[21] Ibid
[22] Ibid

Annex F

Impacts on Sediments

This section describes the impacts from the construction and operation of multiple hydropower projects on sediments in the area of management.

F.1 Overview

River systems comprise not just water flowing through the river channel but also the sediment suspended in the water column or deposited along the riverbed and banks. The erosion, transportation, and deposition of these sediments by the river's water during its passage to the sea shapes the features associated with river channels, such as meanders, sandbars, pools, and deltas. Working and reworking the sediments, the river creates and maintains complex, shifting mosaics of features that provide the diversity of habitats for its living organisms. Maintenance of these habitats is dependent on a continuing supply of the raw material—silt, sand, gravel, cobbles, and boulders—from the riverbed and the wider landscape. The same raw material maintains banks, shorelines, and the riverbed in which the foundations of bridges are sunk (Annandale and HBP 2014).

Dams form barriers to the transportation of much of this raw material, with sediments dropping from suspension as the river slows upon entering the reservoir. The finer sediments may stay in suspension and pass through the dam outlets during floods and, sometimes, coarser material is scoured out through bottom gates to increase storage in a sediment-choked reservoir. Thus, dams can change the total amount of sediments available to the river downstream, with a proportion of a river's sediment load possibly permanently trapped by the reservoir.

If sediments are trapped this way, downstream reaches are starved of them and may become "sediment hungry," eroding their bed and banks at higher than natural rates. Channel adjustments may manifest as changes in channel width, bed level, and slope; down-cutting and entrenchment of the channel; and bed armoring or channel straightening. Land may be lost through bank slumping, with bridges and roads threatened. The extent to which any of these will occur depends on how much the dam changes the river's ability to transport sediment through flow changes, the amount of sediment withheld by the reservoir, and the erodibility of the bed and banks.

As the river's flow and sediment regimes are altered by dams, the interplay of these two forces determines how the downstream physical environment changes. Sediments may decrease in the downstream river because they are trapped in the reservoir, causing downstream erosion, or they may increase because the remaining flow in the river is insufficient to transport the sediments still draining in from the downstream catchment. If sediments are flushed from the reservoir periodically, then periods of low sediment loads could be interspersed with intermittent periods of heavy, possibly anoxic sediments moving downstream; together, the two conditions cause extreme conditions, neither of which is natural.

In whatever way the channel adjustments play out, there will be impacts on the downstream riverine habitats, perhaps through sediments clogging important spawning grounds, habitats degrading through erosion, floodplains declining in extent and fertility, pools filling with sediments, or banks collapsing. All of these changes have implications for the riverine plants and animals, as well as for cultivated land adjacent to the channel (Annandale and HBP 2014).

F.2 Impact on Sediment in the Area of Management

This section presents an overview of the sediment profile in the area of management. Introducing hydropower weirs and impoundments into the main rivers in the area of management will:

- Trap all gravels and most sand-sized material, with knock-on effects on aquatic habitats in the downstream river.
- Increase erosion in the downstream river partly as a result of sediment trapping but also through more constant discharge in narrow flow bands, which removes riparian vegetation through inundation and water logging or hydropeaking.
- Significantly alter the pattern of sand transport in the river, with sand discharge limited to periods of sediment flushing when sand will be released in high concentrations over short periods of time.

The HPPs' actual operating rules are likely to differ from the proposed ones, particularly given the apparent lack of systems to coordinate sediment flushing among different projects. This lack of certainty is a major question for sediment transport in the future, which is described in more detail below.

F.2.1 Impacts on Sediment Transport

Each HPP in the Jhelum and Poonch catchments will affect the movement of sediment locally and further downstream. In the Jhelum, where there are numerous intrabasin transfers, changes in sediment loads will affect both the donor and recipient catchment.

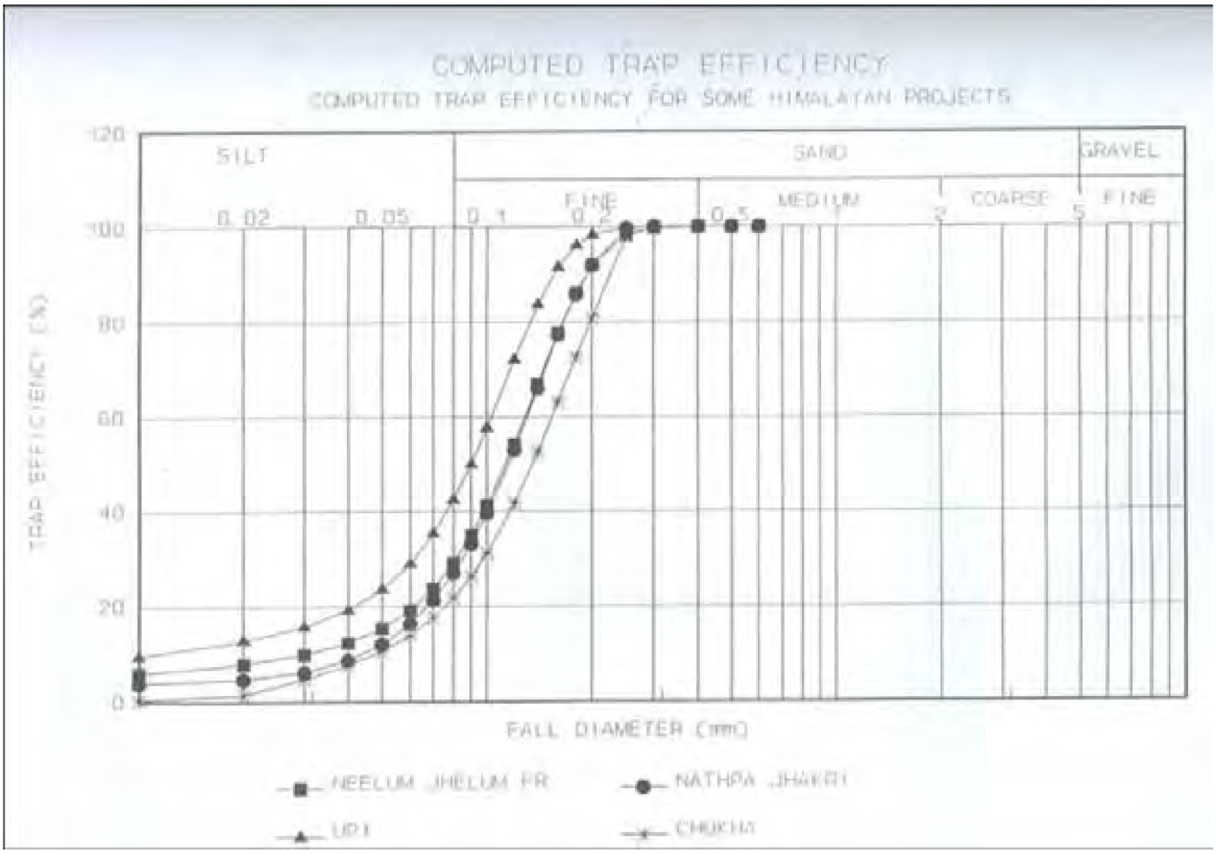
The flow and sediment changes identified in the ESIA of each hydropower project site are summarized in **Figure F-1**. Where possible, the fate of gravel and coarser sediment, sand, and silt and clay have been summarized separately. Collectively, these projects will induce large-scale changes to the Jhelum catchment as discussed below.

Large quantities of sand and gravel will be removed from the river system. The trap efficiency of each impoundment varies and is related to the water velocity and sediment characteristics of the river. An example of computed trap efficiency by grain-size (fall velocity) for the Neelum-Jhelum hydropower project and other Himalayan hydropower projects shows that most silt is transported through impoundments, but sand trapping increases with grain-size, with 100 percent of medium-sized sand and coarser material trapped (**Figure F-1**). Based on a total sediment estimate of 50 metric tons per year for the Jhelum River and the assumption that 15 percent is bedload, an average of 7.5 metric tons per year of coarse material will be trapped. This material is not readily flushed from impoundments and will be deposited within their "dead" storage area. Once sand and gravel deposits have reached the toe of the dam wall, the coarse material can be removed from the impoundments as bedload via low-level gates or sluice gates.

The time it will take for sand and gravel to deposit until it can be passed as bedload depends on the rate of gravel inflow, the morphology and volume of the impoundment, the depth and configuration of flushing gates, the frequency of flushing (which can move gravel further into the impoundment), and the rate and degree of drawdown associated with flushing. Sediment modelling results contained in the Mahl Hydropower Project Feasibility Study (SIDRI 2017) show the predicted change in grain size discharged from the dam over a 20-year period, reflecting this deposition (**Figure F-2**). At Mahl, it is estimated that sediment equilibrium will require about 15 years, with virtually no discharge of material greater than 0.2 mm prior to this time.

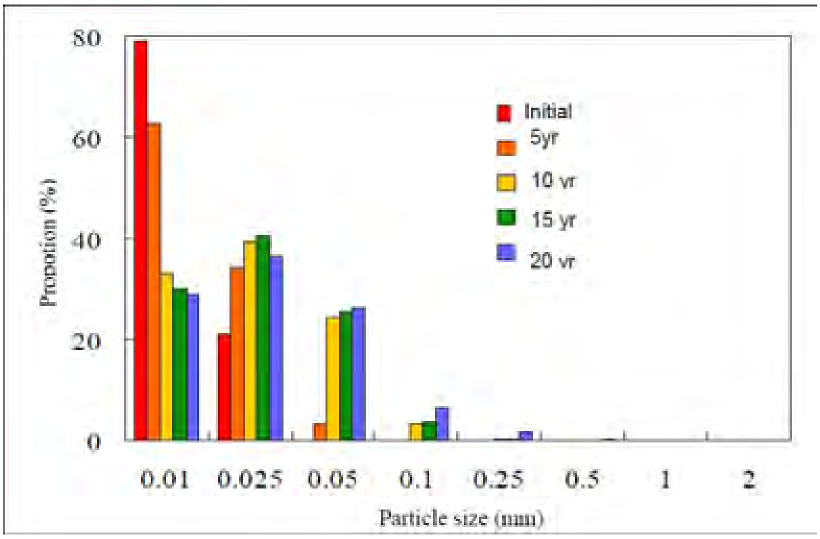
Table F-1 provides a summary of flow changes and sediment-management approaches for HPPs in the Neelum-Jhelum-Poonch rivers. **Table F-2** shows examples of the estimated time for sediments to fill the dead storage of reservoirs in HPPs based on dead-storage volumes and bedload-sediment inflows. These estimates reflect the duration when the downstream environment will receive very low sand or gravel inputs. Flushing may accelerate the discharge of sand to some degree, but gravels will generally be retained until an "equilibrium" with the impoundment is reached.

Figure F-1: Calculated Trap Efficiency by Grain-Size for the Neelum-Jhelum and Other Regional Hydropower Projects



Source: Norconsult and Norplan 1997

Figure F-2: Sediment-Modelling Results for the Mahl Hydropower Project



Source: SIDRI 2017a

Table F-1: Summary of Flow Changes and Sediment-Management Approaches for HPPs in the Neelum-Jhelum-Poonch Rivers

HPP/River	Change to upstream flow	Change to downstream flow	Change to sediment transport: gravel and coarser	Change to sediment transport: sand	Change to sediment transport: silt and clay
Kishanganga impoundment on Neelum/ discharge into upper Jhelum	7 km impoundment with 20 m operating range	Reduced by 58.4 m³/s (avg) diversion into Jhelum when flow is sufficient; Minimum of 9 m³/s released to the Neelum River as EFlow	Trapped and retained until equilibrium is reached with low-level outlets	"Sluiced" to downstream river without water remaining above dead- storage level; deposition in dead area until equilibrium is achieved with low-level outlets	Proportion equivalent to flow diversion is directed into Lake Wular, while the remaining is discharged into the Neelum River; some coarse silt is likely to be trapped
Neelum-Jhelum impoundment on Neelum/ discharge into lower Jhelum	Inflow reduced up to 58.4 m³/s by the Kishanganga diversion	Reduced by 280 m³/s diversion to the Neelum-Jhelum HPP and up to 58.4 m³/s diversion by Kishanganga; 3 m³/s environmental release to the Neelum River	3.4 Mt/yr is trapped in impoundment; water level is reduced in monsoon to promote deposition below active storage level; during peak flows, water level is reduced and bedload passes through large low-level outlets	3 Mt/yr is deposited within active storage level, flushed at the end of dry season via low-level outlets; up to 2.9 Mt/yr is diverted with flow to powerhouse and removed in settling basins, discharged to lower Jhelum in pulses	Diverted to powerhouse or transported through impoundment; some deposition of coarse silt in impoundment and settlement basins
Kohala impoundment on middle Jhelum/ discharge into lower Jhelum	Increased by 58.4 m³/s (avg) as a result of the Kishanganga diversion; pattern affected by upstream HPPs	Reduced by 425 m³/s (avg) diversion, net reduction = 366.5 m³/s; EFlow release of 30 m³/s to Jhelum	Accumulated until equilibrium is reached with sluice gates	Retained in reservoir, flushed when flow rate is >1,000 m³/s; if target flow does not occur annually, conduct sediment flushing between 550–990 m³/s	Diverted into lower Jhelum via powerhouse in proportion to water diversion; some coarse silt will likely be trapped

HPP/River	Change to upstream flow	Change to downstream flow	Change to sediment transport: gravel and coarser	Change to sediment transport: sand	Change to sediment transport: silt and clay
Balakot/Kunhar	No change to annual flow; pattern affected by two upstream HPPs	Pattern altered by HP operations; no change to annual flow	Trapped and retained until equilibrium is reached with low-level outlets	Retained and flushed annually at flow rates of 150–300 m³/s into lower Kunhar	Discharged via powerhouse into the Kunhar River; some coarse silt will likely be trapped
Patrind impoundment on Kunhar/ discharge into lower Jhelum	Pattern affected by upstream HPPs; no change to annual flow volumes	Sept–May: discharge to lower river reduced to 2 m³/s; other months: Discharge (Q) reduced by 153 m³/s	Trapped and retained until equilibrium is reached with low-level outlets, then discharged into Kunhar	Retained and flushed into lower Kunhar	Diverted into lower Jhelum via powerhouse in proportion to water diversion; some coarse silt likely to be trapped
Mahl/ Lower Jhelum	Flow patterns altered by operation of upstream HPPs; upstream water level controlled by discharge from Kohala; no change to annual flow volumes	Discharge into Azad Pattan impoundment	Trapped and retained until equilibrium is reached with low-level outlets, then discharged into lower Jhelum (head of the Azad Pattan impoundment)	Retained and sluiced at flows of 1350–2000 m³/s via sluice gates; draw-down flushing at Q>2,000 m³/s via low-level outlets	Discharged via power station; some coarse silt is likely to be trapped
Azad Pattan/ Lower Jhelum	Flow patterns altered by operation of upstream HPPs; upstream water level controlled by the Mahl HPP's 22 km reservoir; no change to annual flow volumes	Discharge into the head of the Karot impoundment	Trapped and retained until equilibrium with level of low- level outlets, then flushed into lower Jhelum (head of the Karot impoundment)	Flushing via low-level gates at the start of monsoon between 500 and 1000 m³/s	Discharged via power station; some coarse silt is likely to be trapped
Karot/ Lower Jhelum	Flow pattern altered by upstream HPPs; upstream water level controlled by the Mahl HPP's 27 km impoundment; no change to annual flow volumes	Discharge into Mangla Reservoir	Trapped and retained in impoundment until sill height is reached, then flushed with sluice gates; no low-level outlets	Trapped and retained in impoundment until sill height is reached, then flushed using sluice gates; no low-level outlets; some sand may be sluiced at minimum-operating-level water	Discharged via power station; some coarse silt is likely to be trapped
Gulpur/ Poonch	None	Up to 194 m³/s diverted to powerhouse via tunnel, re-enters the downstream Poonch River; flow pattern modified by HPP, but annual flow volume remains unchanged	Deposited upstream of weir on the Poonch River, gravel periodically flushed	Deposited upstream of weir, periodically flushed	Diverted in proportion to flow diversion and discharged via powerhouse

Note: Information is extracted from ESIAs and may not reflect final agreed operating conditions.

Table F-2: Estimated Time Required For Gravel and Coarse Sand to Achieve Equilibrium in Reservoir

HPP	Reservoir volume	Bedload input (1.8 Mt/m^3)	Estimated time to achieve equilibrium
Balakot (Mirza 2013)	Total: 12.6 Mm^3 Dead: 10.04 Mm^3	0.35 Mt/yr = 0.19 Mm^3/yr	~ 50 years
Neelum-Jhelum (Norconsult and Norplan 1997)	Total: ~8 Mm^3 Dead: 5.2 Mm^3	3.4 Mt/yr = 1.8 Mm^3/yr	~ 2.75 years
Kohala (BIDR 2016)	Total: 15 Mm^3 Dead: N/A Assume 90% = 13.5 Mm^3	5 Mt/yr = 2.8 Mm^3/yr	~ 5 years

Note: Estimated time between dam establishment and discharge of gravel and coarse sand to downstream river

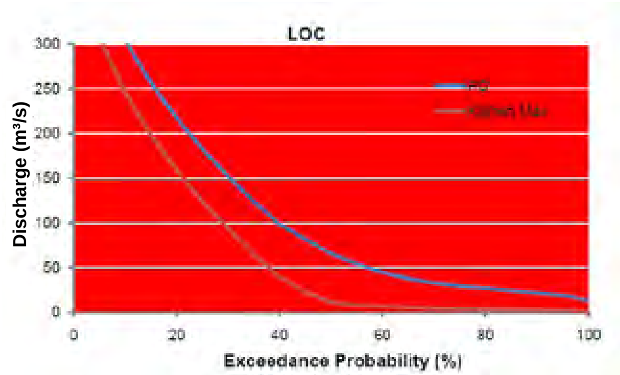
The pattern of sand transport in the river will be highly altered—discharge will be limited to periods of sediment flushing when sand is released in high concentrations over a short time. Although annual sand loads in the river may remain similar before and after the establishment of the HPP, very little sand will be discharged for effectively 50 or more weeks of the year before the release of the annual sand load from the impoundment for a limited time. A hypothetical situation is provided where the average monthly unregulated sand loads at Patrind are compared to sand loads under a "capture-and-release" sand-flushing regime (**Figure F-3**).

- The hydraulics of river channels will change—rivers from which water has been diverted will experience a reduction in river energy, while those receiving the water will have increased river flow and energy (**Figure F-4**). Of particular note is the confluence of the Neelum and Jhelum rivers, which will see a large decrease in flow, gravel delivery, and altered patterns of sand delivery. Downstream, additional changes will occur because of the flow diversion from the Kunhar River into the Jhelum and the rapid increases in flow and river energy associated with the inflow from the Neelum-Jhelum and Kohala diversion projects.

Figure F-3: Hypothetical Change to Sand Delivery Based on Sand Loads at the Patrind HPP Site

Note: Based on assuming 90 percent sand-trapping efficiency and sediment flushing during the recession of the monsoon

Figure F-4: Example of Reduction in Flow Associated with Water Diversion at the Kishanganga HPP



Source: HBP 2011

- Smaller pulses of sand and silt captured in sediment traps upstream of powerhouses will be episodically flushed to the downstream river.
- The diversions will direct equivalent proportions of silt and clay, and lesser portions of sand, as water from one river to another. These changes will alter the dispersal patterns of sediment and affect water quality in both the contributing and receiving basin.

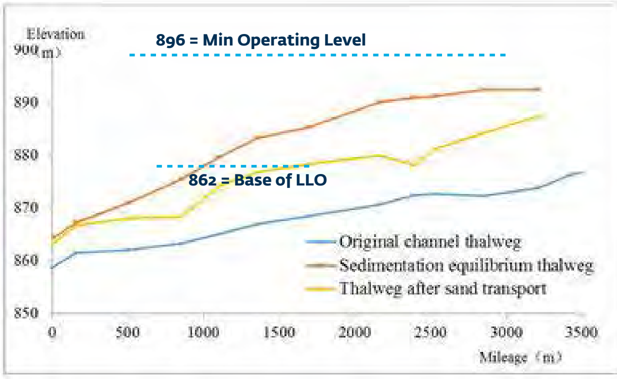
Most projects plan to produce power continuously in the wet season but focus hydropower operations during peak periods. If each HPP adopts this pattern, the entire river will experience large water-level variations daily (or sub-daily), which will create high river-energy conditions and may exacerbate erosion across the catchment.

The sediment-management regime of most projects aims to promote sand deposition within the impoundment to minimize ingress to the turbines and wear and tear on the infrastructure. This is combined with annual sediment flushing to maintain sufficient capacity within the impoundment to provide operational flexibility. Although some sand may be flushed annually, gravel and coarser sand will not be transported downstream until an equilibrium is reached in the impoundment, whereby the deposits reach the toe of the dam and the surface of the deposits reaches the lowest outlet level. This approach will result in the deposition of deltas at the head waters of the impoundment and may increase upstream flooding during high-flow events because of reduced channel capacity. **Figure F-5** shows the morphology of an impoundment following equilibration with gravel inputs. As described in the ESIA documents, all projects will trap virtually all gravel entering the impoundment. Some projects have very low-level outlets specifically to reduce the length of time until coarse material can be flushed downstream, but other projects will promote deposition until the sediment deposits reach the level of the sluice gates. As discussed previously, time-frames required to achieve equilibrium are difficult to identify and vary owing to the morphology of impoundments, rate of sediment input, and upstream activities. The loss of gravel to trapping in upstream hydropower projects or aggregate mining will reduce its availability to downstream projects, thereby taking longer to achieve equilibrium.

Annual sediment flushing may negatively affect the downstream river system and HPP projects, especially in the Lower Jhelum cascade where sediment flushed from one impoundment will directly enter the next one downstream (**Figure F-6**). Sediment concentrations during flushing will be very high; for example, it is calculated at 44 kg/m³ = 44 g/L at Kohala, well above natural sediment concentrations. These flushes may generate large turbidity plumes that propagate downstream, coating downstream riverbed and banks as well as creating hardpans on exposed riverbanks once flows recede. The nature and extent of impacts will vary with distance from the dam, the flow pattern during flushing, and flow volume and duration following the release of the large sediment load. Impacts may be mitigated if flushing coincides with high-flow events; however, such events could increase the risk of flooding downstream.

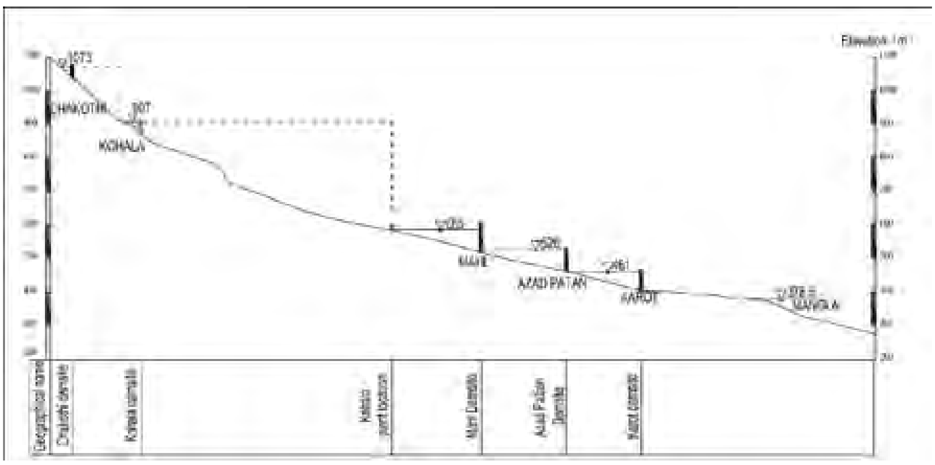
The HPP project descriptions and sediment-management approaches are largely based on average conditions, which rarely occur. Consideration needs to be given to how an impoundment will be managed in an exceedingly large sediment inflow event, such as a major landslip or avalanche. In the Jhelum Basin, the reservoirs are small compared to the "annual average" inflow-sediment volumes and they do not have capacity to store sediment loads equivalent to several "average" years. Sediment loads are highly variable and episodic events could deliver multiple times of the average load in a brief period. These situations would require more frequent flushing.

Figure F-5: Long Section of Hydropower Impoundment Showing Sand and Gravel Deposition with and without Sediment Flushing



Note: Sediment deposits need to advance to the toe of the dam and base of the low-level outlet before gravel transport to the downstream river can commence.

Figure F-6: Schematic Diagram of the Lower Jhelum Cascade



The following highlight some of the more localized geomorphic, aquatic ecology, and hydropower risks related to the flow and sediment regulation implemented in the system.

F.2.2 Geomorphic Impacts

The river channel immediately downstream of a dam will have a high risk of scour because water discharged from the dam erodes the river with no subsequent sediment deposition.

Water diversions will reduce the sediment transport capacity of the rivers for significant lengths downstream of the diversion site for most of the year. This will reduce the grain sizes to be transported by the river, resulting in increased sedimentation. A reduction in river levels can also promote vegetation encroachment. These processes may reduce channel capacity so that when a major event occurs, flooding will occur at lower discharge rates as compared to pre-dam conditions. The risk of these processes occurring is linked to the frequency of large flood events to maintain channel capacity. Such risks are lowered if large flows are retained in the "donor" river during each monsoon season.

Channel capacity downstream of diversion projects could also decline if accumulated sand in the impoundments is flushed into the original river channel and the river does not have sufficient energy to transport the material. There is also a risk that "flushed" material deposited on riverbanks will become cemented and affect riparian habitats. The steep nature of the river channels, high river energy, and inflow of additional tributaries can mitigate these risks if flushing coincides with high-flow periods.

Tributaries downstream of HPPs diverting water out of catchment will be discharging into lower base levels. This will increase the water-surface slope of the tributary, river energy, and erosion in the lower channel of the tributary. The river from which water has been diverted will be able to transport less sediments and sediment inflows from tributaries may deposit and build "tributary bars" or infill the channel. The opposite situation may arise in rivers receiving additional flow, as base levels are increased and tributaries adjust to a higher base flow. The risk of impacts is related to the degree of flow change and relative inflow patterns of the tributaries and mainstem. If hydropower projects are truly run-of-river, then the relative timing and magnitude of flows in tributaries and the mainstem will not change and the risk is reduced.

Although most impoundments are relatively small, they still extend one kilometer or more upstream. Peaking operations can create fluctuating impoundment levels of several meters per day, which may destabilize hillslopes and inhibit the establishment of riparian vegetation, leading to increased bank erosion.

Bed-material grain size in river channels downstream of HPPs will increase because sands and gravels transported from the river channel are not replaced.

F.2.3 Impacts on Aquatic Ecosystems

Significant changes to the flow and sediment regime of the rivers will alter the distribution and quality of aquatic ecosystems as follows:

- A large reduction in gravel (and larger) transport through the river systems will result in a decline in the availability of aquatic habitats. The bedload grain-size distribution results suggest that gravel is transient in the rivers, with high flows able to rapidly transport this material downstream. This suggests that any gravel habitat that was deposited at the end of the wet season will only be available in the dry season before being removed by the next high flows. Due to gravel trapping in hydropower projects, only gravel derived from the catchment downstream of HPP sites will be available for replenishment. Gravels are a key aquatic habitat for fish and a reduction in this habitat may lead to an overall decline in the fish population.
- The specific impact to any area will depend on its location with respect to HPPs and the area and sediment input from the unregulated catchment between the upstream HPP and the site. Impacts to specific areas may vary over time as well. For example, erosion and loss of gravels and sands may occur for months to years during periods of "normal" HPP operations. However, following sediment flushing, the area may experience high levels of sand and silt deposition. These factors need to be considered when developing a sediment-management plan.
- The conversion of rivers into impoundments will alter the characteristics of the habitat, such as water depth, flow velocity, and sediment transport. Some of the impoundments in the Jhelum-Poonch catchments are relatively small, but in the lower Jhelum, the establishment of a cascade will convert 145 km of free-flowing river into four ponded storages. Upstream of the Kohala discharge point, the lower Jhelum River will have highly reduced flow and sediment transport because of the upstream diversion projects. These two impacts will fundamentally alter the habitat characteristics of the lower Jhelum River.
- Nutrient transport is linked to that of fine silts and clays and will be similarly affected as these sediment

size fractions. Large quantities of nutrients will be diverted from river catchments and some will be trapped within impoundments. These changes will alter the availability of nutrients to the aquatic ecosystem and riparian vegetation.

- The flushing of sediments will create large sediment plumes that may coat and infill riverine habitats as well as blanket riparian zones with fine sediment and create hardpans. Sediment flushing can also release large volumes of low oxygen or contaminated water from the depths of the impoundments.
- The ESIAs did not provide information about sediment quality, so it is not possible to predict whether the capture or dispersal of contaminated sediments will be an issue in HPPs.
- Water quality in rivers may be affected by impoundment and intra-catchment diversions. Most proposed impoundments are relatively small with only a few days of retention time. The risk of water-column stratification in these waterbodies is low. In the lower Jhelum cascade, however, there are water-quality risks associated with the extended storage of water in successive impoundments. Light clarity will likely be high in these water bodies as a result of sediment settling with heightened risks of algal blooms. Water quality will likely be affected in rivers downstream of diversion projects, where the available dilution provided by river flow is substantially decreased. A potentially high-risk area is Muzaffarabad, where flow rates in the Neelum and Jhelum rivers are predicted to decrease from around 650 m^3/s to less than 100 m^3/s, reducing the available dilution for industrial, municipal, or domestic wastewater discharges by more than sixfold. This may not be a high risk at present, but if population growth and industrialization continue, the risk will increase.

F.2.4 Impacts on Areas of High Ecological Sensitivity

Chapter 3 of this report identified two areas within the basin of high ecological sensitivity: the Mahl River, a tributary of the lower Jhelum, and the Poonch River, from the Line of Control to the Mangla Reservoir.

No HPPs are planned for the Mahl River, so geomorphic changes will be limited to the confluence of the Mahl and Jhelum rivers. Due to the high degree of sediment trapping at the confluence of these two rivers, the Jhelum River channel will very likely undergo incision as a result of a lack of sediment deposition. This may alter the hydraulics of the confluence and increase the slope of the lower Mahl River because of a reduction in the Jhelum's base level. Although the Jhelum is likely to deepen, transient cobble bars may be formed at the confluence because sediment is not being transported by the highly regulated Jhelum and deposits into the Mahl during high flows (for example, flood flows are reduced in the Jhelum relative to the Mahl).

In the Poonch, the timing and magnitude of sediment transport will be affected by sediment trapping upstream of the weir and the localized diversion of flow. Specific impacts are likely to include erosion downstream of the HPP. As there is only one HPP that can periodically flush accumulated sediment down the natural river channel, a sediment-management plan can be developed to promote the movement of sediment through the impoundment to minimize downstream impacts.

F.2.5 Sediment-Management Approaches

Available information clearly indicates that the rivers' sediment regime will be highly altered under the development scenarios. Sediment-management approaches need to be developed to minimize and mitigate these impacts, where practicable. A sound sediment-management strategy will require the following components:

- A better and more up-to-date understanding of sediment-transport processes in the basin is needed. The sediment analysis was based on environmental impact assessments that were decades old with limited measurements using a range of techniques. Coordinated sediment transport and geomorphic monitoring throughout the basin is required to reflect the current situation more accurately. Monitoring upstream and downstream of existing HPPs can also verify some of the assumptions about trapping efficiency and channel changes related to the projects. This information should form the baseline for developing a long-term strategy and against which future changes can be assessed.
- Areas of high ecological concern, such as spawning grounds or exposed cobble bars, should be surveyed and the grain-size characteristics of the substrate should be quantified. The maintenance of these areas should be set as targets for the sediment-management plan.
- A basin-wide, long-term sediment-management strategy should be developed based on the locations of HPPs, the timing of implementation of each project, the potential for each project to discharge sand annually, and the time required for coarse sands and gravels to be discharged from the impoundment. Sediment routing (flows with high sediment loads are allowed to pass through the

impoundment) and flushing can then be coordinated to ensure the continued delivery of sand and coarser material to river reaches of high ecological importance. Ideally, a sediment model should be developed for the basin to optimize the sediment-management strategy.

- The coordination of sediment flushing between projects should enhance the downstream transport of sediment but also prevent sediment concentrations and flow levels associated with flushing from causing harm. Such harm includes flooding or choking of the riverbed and banks from the deposition of large volumes of fine-grained sediment (as might occur if flushing is completed during the dry season).
- Set up a coordination group that promotes communication between the HPPs leading to the development of a catchment-wide sediment-management plan.

F.2.6 Socio-economic Impacts

This section presents an overview of socio-economic impacts from changes in sediment load and availability in the area of management.

As discussed in previous sections, bedload will be trapped while suspended sediment and sand fractions will be released when the reservoirs are flushed. Sediments are expected to accumulate in the reservoirs for between five and 15 years, although the actual length will vary depending on the reservoir size, sediment inflow, and flushing design. As the cascade of hydropower projects comes into place, the following outcomes are expected:

Boulders, Cobbles, and Gravel

Boulders, cobbles, and gravel (bedload) for mining will be available only in the river segments upstream of the dams that are first in the catchments. This means the Suki Kinari HPP in the Kunhar River, the Athmuqam HPP or Dudhnial HPP in the Neelum River, the Kohala HPP in the Jhelum River, and the Gulpur HPP in the Poonch River. Floods will deposit the bedload in the reservoirs where heavier fractions will settle at the upstream end of reservoirs. Downstream of dams of these projects, sediment will flow in from the tributaries into the reservoirs or be deposited in the main stem from where it could be mined.

Following the dam's construction, the mining of boulders, cobbles, and gravel could be directed to the upstream end of reservoirs where these fractions will settle. Larger boulder fractions will settle first and likely remain in place as the water velocity will not be high enough to move them even during high floods. Miners also cannot remove the larger boulders given their weight. Cobble and boulder deposits will gradually move toward the dam but could still be mined once deposited. Initially, dam operators may want to see a build-up of deposits to restrict the movement of cobbles and gravel toward the dam. Later on, however, they would likely prefer removing cobbles and gravel at the upstream end of reservoirs to maintain storage levels and extend reservoir life. Access, if not already available, may need to be provided to the community to reach the deposited sediments at the upstream end of the reservoirs.

Suitability of cobbles collected from riverbeds for aggregate production should also be investigated. The hydropower industry does not use aggregate produced from sediment mined from riverbeds, as the strength achieved in concrete does not meet the specifications. It is likely that the aggregate produced from cobbles collected from riverbeds is not suitable for the construction of residential and commercial buildings, particularly for reinforced-cement-concrete structures. Further studies are needed to determine the risks involved.

Sand

Availability of sand will be initially restricted when reservoirs reach an equilibrium. Some sand will be released from the sand traps installed at the dams to reduce the flow of sediments into the powerhouse turbines. After the reservoirs have reached an equilibrium, coarser sand fractions will be flushed typically once a year, but sand will not be available downstream for the rest of the year. Communities can mine sand, but the location of sand deposits will shift as the dams are constructed and operated. The socio-economic impacts related to the availability of sand after reaching equilibrium will therefore be limited and manageable. As in the case of cobbles and gravel, access may have to be provided to the community to reach the deposited sediments.

F.2.7 Impacts on Other HPPs

Sediment flushing will affect downstream rivers and HPPs. For example, the lower Jhelum River will experience large inflows of water and sediment whenever the Neelum-Jhelum, Kohala, or Patrind projects implement flushing. Simultaneous flushing by the projects may create huge sediment loads and floods in the lower river. Managing these flushes will require coordination to maintain water levels within safe limits and prevent the deposition of large sediment volumes within the lower impoundments. Flushing within the cascade (for example, from Mahl to Azad Pattan) will require similar coordination.

If flushing coincides with high-flow events, sediment and water pulses, combined with natural inflows, may increase flooding, especially if the channel has been infilled by sediment from tributaries.

Once the impoundments reach equilibrium with incoming bed material, flushing may become viable. In the lower cascade, the movement of large material from one project into the headwaters of the next downstream can increase bed levels and affect storage capacity.

Flushing at the end of the wet season has been proposed to increase water-storage capacity for peaking during the dry season. This could increase sedimentation in the downstream river channel, reducing its capacity for the first high-flow events of the following monsoon season.

F.3
Summary of Findings

To develop a sustainable hydropower development strategy, it is important to answer the following questions on changes in sediment transport in the catchments:

- *Which reservoirs will trap bedload sediment?* All reservoirs are predicted to trap nearly all bedload sediment. Sediment flushing is expected to mobilize sand, but bedload comprising gravel and coarser material will remain trapped until equilibrium is achieved and the material can move downstream through a gate. Bedload transport will continue and increase in unregulated reaches of the lower rivers and abruptly end at each impoundment before recommencing downstream of the dam. However, the riverbeds downstream of impoundments will be armored as material is transported but lesser of it becomes available as bedload. This punctuated capture of material, combined with armoring of the riverbeds, will disrupt the connectivity of the river system and promote major geomorphic changes. New HPPs constructed upstream of existing projects will capture the bedload, meaning there will be less input for the downstream projects in operation. Because of this, it is difficult to determine when impoundments will achieve equilibrium with bedload transport.
- *When will hydropower projects attain equilibrium with the sediment load?* HPPs are unlikely to ever achieve a true equilibrium because of numerous factors controlling sediment transport and HPP operations. Over years to decades, a dynamic equilibrium will be reached reflecting the variability of the system, including:
  - ¤ Variable sediment loads and delivery patterns
  - ¤ Episodic extreme events resulting in the delivery of large instantaneous loads
  - ¤ The flushing regime implemented at a HPP
  - ¤ The operating regime of a HPP, which can result in the movement of material into different parts of the impoundment
  - ¤ The operations of upstream HPPs affecting bedload and sand inputs

  According to the ESIAs of hydropower projects, it usually took several decades before the active storage capacity of the impoundments reached an equilibrium with the incoming sediment load. However, these predictions were based on annual sediment loads, annual flushing, assumptions about the efficacy of flushing regimes, and catchment conditions; they did not incorporate the impacts of upstream HPPs on sediment transport. For example, the Mahl HPP is unlikely to receive its estimated sediment load of 30 metric tons per year for decades into the future owing to the capture of material in upstream impoundments (SIDRI 2017). Therefore, time frames for achieving a sediment equilibrium within impoundments is contingent on each impoundment upstream achieving a balance.
- *How will sediment patterns change above and below each HPP?* This is summarized in **Table F-1**. Sediment trapping will reduce the daily transport of sand and coarser material downstream of HPPs, with episodic pulses of sand released from impoundments. Diversion projects will reduce the transport of silt and clay downstream in the donor basin and increase transport in the receiving basin. The diversion of water will also affect the transport capacity of rivers downstream of diversions, promoting large-scale geomorphic response of the river channel, such as narrowing and infilling. Sediment transport upstream of HPPs will be affected by sediment trapping and operations of existing upstream HPPs.

F.4
Information Gaps

The available sediment information provides an internally consistent, large-scale picture of sediment transport in the catchments. The most recent results were already 10 to 20 years old, so sediment- regime changes associated with catchment development or climate change over the past two decades have not been reflected in the data sets and are beyond the scope of this project. Before a robust understanding of climate-related changes could be gained, it is necessary to find out how existing hydropower stations and catchment activities have been affecting sediment transport.

While the existing information provides a catchment overview, information about local geomorphic processes is missing. These localized, reach-based relationships have a controlling influence over the biodiversity and ecosystem conditions of in-channel and riparian habitats.

A key question about sediment transport in the future is the uncertainty associated with how HPPs will operate versus how they are proposed to operate. Of particular concern is the lack of established systems to coordinate sediment flushing among different projects.

These information gaps could be addressed, at least partially, by implementing the following:

- Measure bedload movement using the Acoustic Doppler Current Profiler technology. This instrument normally measures discharge but can be adapted to calculate the average rate of bedload movement across a river profile. Other remote-sensing techniques could also be used to obtain *in situ* grain-size. These types of measurements would provide a quantitative understanding of bedload movement and sediment size that are critical for understanding sediment transport in river systems.
- Map the sediments forming in-channel habitats, such as gravel beds or sand bars, at a reach scale. This information would allow a better understanding of how these critical habitats will likely change under altered sediment-transport and flow regimes. Photo-monitoring points could be set up to take repeat photos from the same vantage point to capture changes to sediment and channel characteristics.
- Based on the river-reach maps, quantify the relationship between discharge and sediment movement, particularly reach-specific information on the sorting of sediment size-fractions to form habitats. This information is necessary to devise proper EFlow regimes.
- Gather more information about how HPPs will operate and be coordinated. The operations of HPPs will combine to produce an entirely new flow and sediment regime in the river. An understanding of the interaction of individual regimes, such as in terms of sediment flushing, is needed to identify the right management strategies. This can be done through a catchment hydropower user group or equivalent.
- Consideration should be given to the development of sediment-flushing guidelines to provide guidance on the seasonal timing of flushing, flow rates, suspended sediment concentrations, flushing durations, monitoring, and requirements for the notification of downstream communities and HPPs.

Annex G

Assessment of Impacts on Ecology

This section summarizes the development impacts from multiple hydropower projects on the basin's aquatic and terrestrial ecology.

G.1 Impacts on Aquatic Ecological Resources Using DRIFT Modelling

Impacts on the aquatic ecological resources were assessed using the DRIFT Decision Support System (DSS). It is an internationally recognized software model that employs a multidisciplinary team to analyze the likely effects of a range of flow scenarios. DRIFT aims to produce predictions of change in three streams of information—ecological, economic, and social—representing the three pillars of sustainable development. It incorporates a custom-built DSS that holds all the relevant data, understanding, and local wisdom about the river provided by the team of river and social specialists. DRIFT has been used in many transboundary or basin-wide water-development investigations over the last 15 years, including numerous applications in Asia and in its country of origin, South Africa (Brown 2009; King and Pienaar, forthcoming; Beilfuss and Brown 2010).[1,2] The methodology has been successfully tested by HBP for several HPPs, including the Kishanganga and Neelum River diversion as a consequence of the construction of the Kishanganga Dam by India, the Neelum-Jhelum HPP, the Kohala HPP, the Karot HPP, the Gulpur HPP, and the Balakot HPP.

The four main aims incorporated into the DRIFT process are to: 1) synthesize present relevant knowledge on the river ecosystem, 2) synthesize present relevant knowledge on use of the river, 3) predict how the river ecosystem could change with water-resource development, and 4) predict how these river changes could affect people and the economy.

G.1.1 Setup of the DRIFT Model

The DRIFT model for the Jhelum-Poonch River Basin (Jhelum DSS) was configured by Southern Waters and HBP with support from IFC (HBP 2018c). A conservative assessment was conducted for a base case assuming flow alterations and barriers to migration created by dams. Impacts on ecosystem integrity were assessed assuming no management. This model has now been updated for this study by combining and extending the DRIFT DSSs used to assess the EFlows of individual HPPs in the Jhelum-Poonch Basin since 2010, namely the Gulpur HPP, the Karot HPP, the Kishanganga HPP, the Kohala HPP, and the Neelum-Jhelum HPP.

The consolidated DRIFT DSS comprises 25 EFlow sites: 20 on the mainstem rivers (the Neelum, the Jhelum, and the Poonch) and five representing key groups of nullahs (**Figure G-1**). **Table G-1** lists the reach represented by each site and also provides each reach's 2012 ecological status, which is used as the baseline integrity (**Figure G-2**) throughout the DSS. For the sites that did not form part of the existing DSSs but for which the response curves and other information were extrapolated, the site for when the extrapolation was done is also provided in **Table G-1**.

Inclusion of Nullahs

The five tributary (nullah) sites shown in **Table G-1** were included to represent key groups of nullahs in various reaches of the mainstem, which are important habitats for migratory fish species and sediment supply. The assumption underlying the inclusion of these nullahs is that although they do not have any HPPs located on them, they are subject to other pressures such as overfishing and mining. Thus, in the DSS, the nullah sites have sufficient functionality to estimate the effects of changing protection levels but not enough to evaluate the effect of locating an HPP on a nullah. The manner in which the nullahs have been programmed in the DSS means that protection measures are assumed to be applied to all nullahs in a group.

Inundation and Dewatered Zones

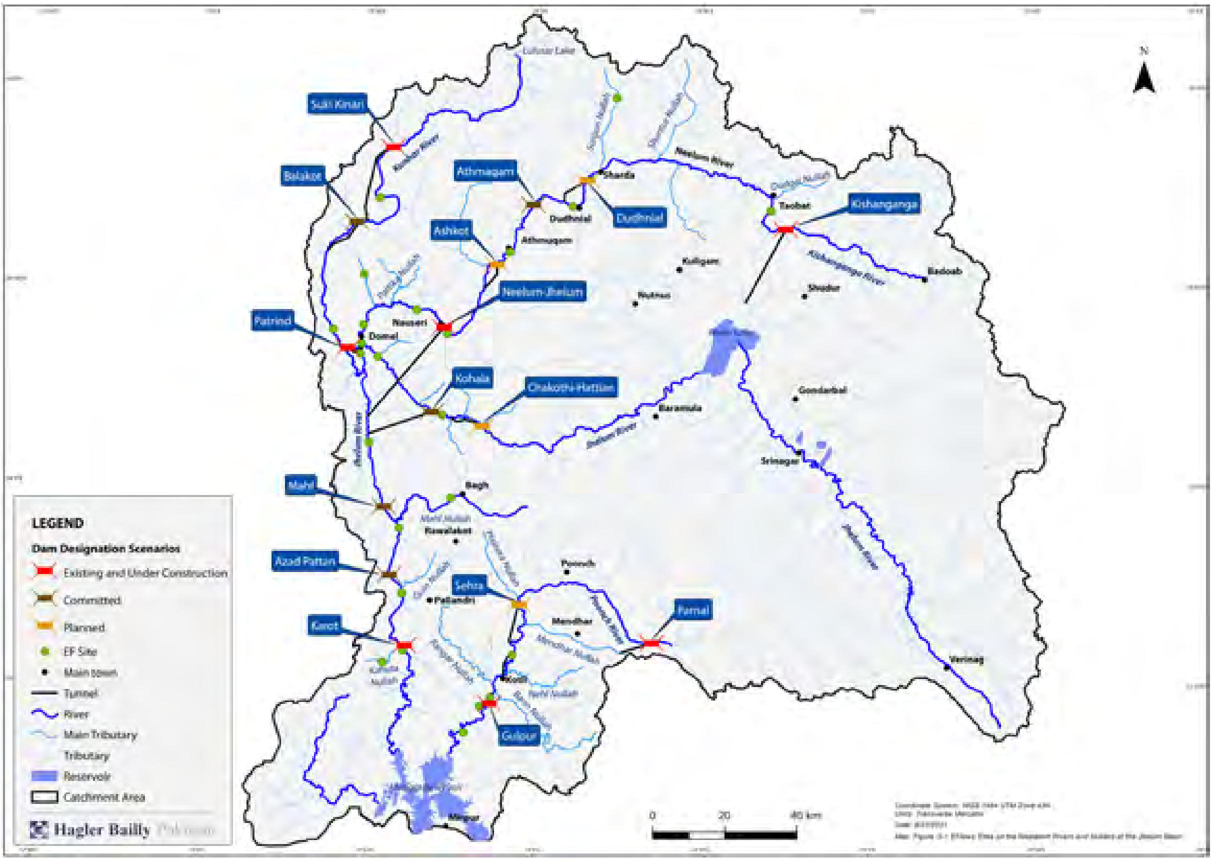
The DSS as it is currently programmed does not account for flooded areas associated with the reservoirs. Each HPP included in the scenarios will have an inundated area upstream of its weir. This inundated zone varies depending on river slope and weir height, but they tend to be between 30 and 70 km for HPPs in the Jhelum Basin. In these areas, riverine habitat is converted to lake habitat and all river features are essentially lost. These areas are neither captured in the DSS nor the maps of the ecosystem integrity linked to the scenarios.

The DSS also excludes dewatered zones of 20 km or less. As such, it includes the dewatered zones resulting from the diversions at the Neelum-Jhelum and Kohala HPPs but excludes those for the likes of the Patrind and Athmuqam HPPs.

[1] http://www.iucn.org/about/work/programmes/water/wp_where_we_work/wp_our_work_projects/wp_our_work_pan/pangani_fa_reports.

[2] The EFA reports 01 to 08, dated 2009, under the EPSMO project at OKACOM www.okacom.org.

Figure G-1: EFlows Sites on the Mainstem Rivers and Nullahs of the Jhelum Basin



Note: Map shows the hydropower projects modeled in the basin-wide DRIFT DSS.

Table G-1: EFlow Sites in the Consolidated Jhelum DSS

	River	EFlow site	Coordinates	Location	Representing	Baseline integrity	Extrapolated from
Mainstem							
1	Neelum	Line of Control	34.6950N; 74.7060E	Upstream of Taobat	Line of Control to Matchal	B	–
2		Dudhnial	34.7050N; 74.1040E	Near Dudhnial	Matchal to Dudhnial	B	–
3		Athmuqam	34.5834N; 73.9088S	Near Athmuqam	Dudhnial to Bata	C	Dudhnial
4		Nauseri	34.3814N; 73,7282E	Upstream of Nauseri	Bata to Nauseri	C	–
5		Panjgiran	34.4408N; 73.6357E	Near Panjgiran	Nauseri to Patikka	C	–
6		Dhanni	34.4408N; 73.6357E	Near Dhanni, immediately upstream of Muzaffarabad	Patikka to Muzaffarabad	C	–
7		Muzaffarabad	34.4020N; 73.4752E	In Muzaffarabad	Muzaffarabad	D	–
8	Kunhar	Khanian	34.7230N; 73.5342E	Between Suki Kinari and Balakot	Upper Kunhar	C	Ambor
9		Paksair	34.4358N; 73.3605E	Between Balakot and Patrind	Lower Kunhar	C	Ambor

River		EFlow site	Coordinates	Location	Representing	Baseline integrity	Extrapolated from
Mainstem							
10	Jhelum	Upstream Kohala HPP	34.1791N; 73.7155E	Upstream of the Kohala HPP	Line of Control to the Kohala Reservoir	C	–
11		Subrey	34.3552N; 73.5195E	Near Paprusa, upstream of the Neelum-Jhelum confluence	Kohala HPP to the confluence with the Neelum River	C	–
12		Ambor	34.3239N; 73.4671E	Downstream of the Neelum-Jhelum confluence, near Charwa	Confluence with the Neelum River to upstream Neelum-Jhelum HPP tailrace	D	–
13		Kohala	34.1078N; 73.4966E	Near Sangal and Kohala gauging station	Neelum-Jhelum/Kohala HPP tailraces to Karot HPP	D	–
14		Mahl downstream	33.9043N; 73.5839E	Downstream of Mahl HPP	Mahl HPP tailrace to Azad Pattan HPP	D	Kohala
15		Azad Pattan downstream	33.7600N; 73.5753E	Downstream of Azad Pattan HPP	Azad Pattan HPP tailrace to Karot HPP	C	Kohala
16		Hollar	33.5875N; 73.6054E	Near Hollar Bridge	Karot HPP tailrace to Mangla Dam	C	–
17	Poonch	Kallar Bridge	33.5785N; 73.9372E	Kallar Bridge	Line of Control to Kotli	C	–
18		Borali Bridge	33.4520N; 73.8580E	Borali Bridge	Gulpur HPP weir to tailrace	C	–
19		Gulpur Bridge	33.4492N; 73.8372E	Gulpur Bridge	Gulpur HPP tailrace to downstream of Gulpur Bridge	C	–
20		Billiporian Bridge	33.3846N; 73.7915E	Billiporian Bridge	Downstream of Gulpur Bridge to Mangla full-supply level	C	–
Tributaries (nullahs)							
21	Neelum	Surgun Nullah	n.a.	Tributaries between the Line of Control and Dudhnial		C	Line of Control
22		Jagran Nullah	n.a.	Tributaries between Athmuqam and Nauseri		C	Mahl Nullah
23		Patikka Nullah	n.a.	Tributaries between Panjgiran and Dhanni		C	Mahl Nullah
24	Jhelum	Mahl Nullah	n.a.	Tributaries between Kohala and Hollar		D	–
25	Jhelum	Kahuta Nullah	n.a.	Tributaries between the Karot HPP and the Mangla Reservoir		C	–

Note: New sites highlighted in green

Figure G-2: Ecosystem Integrity

Ecosystem integrity is an indication of the ecological condition of a part of the ecosystem (such as habitats or fish communities) or of the whole ecosystem relative to its natural condition. Integrity is expressed as an ecological category from A to F as defined below.

Ecological category	Description of the habitat
A	Unmodified: the habitat is still in a natural condition.
B	Slightly modified: a small change in natural habitats and biota has taken place, but the ecosystem functions have essentially remained the same.
C	Moderately modified: loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified: a large loss of natural habitat, biota, and basic ecosystem functions has occurred.
E	Seriously modified: the loss of natural habitat, biota, and basic ecosystem functions is extensive.
F	Critically/extremely modified: the system has been critically modified with an almost complete loss of natural habitat and biota; in the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

Sources of Information

The details behind the setup of the project-specific DSSs have not been included in this report.

- The process followed to set up, populate, and run initial scenarios in the basin-wide DRIFT DSS for the Jhelum Basin, Azad Jammu and Kashmir (AJK), is covered in the Biodiversity Strategy for the Jhelum-Poonch River Basin (HBP 2016a).
- The details of the DSS, indicators, response curves, operational aspects, and the considerations and assumptions underlying the protection levels are covered in the various project reports outlined in **Section 1.7** of the main report.

G.1.2 Results of Scenario Analysis

Scenarios Assessed

Impacts on the aquatic ecological resources were tested using the DRIFT DSS, which evaluated scenarios comprising three levels of HPP development (excluding developments on the nullahs), two levels of management of the downstream river reaches and key tributaries, and variations on HPP operations, including sediment flushing and peaking versus baseload power generation. For each scenario, the DSS predicted overall river condition based on an assessment of changes in key indicators for the next 30 years starting from 2012, with the intervening period defined by the provisions of the scenario.

The three levels of HPP development were defined as: 1) existing or under-construction HPPs; 2) committed HPPs, meaning detailed engineering is at an advanced stage, tariff application at the engineering, procurement, and construction stage has been submitted or approved by the electricity regulator, or a letter of support has been issued by the government; and 3) planned HPPs, meaning a feasibility study has been prepared and a letter of intent has been issued by the government, but detailed engineering has not started (or is at an early stage) and investors other than the initial developer have not been secured.

The two management levels were based on peak power or baseload power generation and the EFlow releases outlined in **Table G-2** and the various management levels agreed with HPP companies outlined in **Table G-3**.

The two management levels were defined as:

- “Agreed,” incorporating various management provisions between the government and individual HPP companies
- “High,” which has more stringent protection levels for the environment than the “agreed” scenario; examples include higher EFlow releases from the Neelum-Jhelum HPP (22.5 m^3/s instead of 9 m^3/s) and baseload instead of peaking operations at the Neelum-Jhelum and the Kishanganga HPPs.

A stakeholder workshop was held in Islamabad in January 2018 to review and test the scenarios encompassing individual changes in flow regime, sediments, management, and fish migration. Details of this workshop are provided in **Annex G.A** of this **Annex G.**

Table G-2: Scenarios Assessed in this Report

Subbasin	HPP	Existing and under-construction		Committed		Planned	
		Agreed management	High management	Agreed management	High management	Agreed management	High management
Neelum	Kishanganga	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s
	Dudhnial					Baseload	Baseload
	Ashkot					Baseload	Baseload
	Athmuqam			Baseload	Baseload	Baseload	Baseload
	Neelum-Jhelum	Peaking EFlow release (9 m^3/s)	Baseload/higher EFlow release (22.5 m^3/s)	Peaking EFlow release (9 m^3/s)	Baseload/higher EFlow release (22.5 m^3/s)	Peaking EFlow release (9 m^3/s)	Baseload/higher EFlow release (22.5 m^3/s)
Kunhar	Suki Kinari	Peaking	Peaking	Peaking	Peaking	Peaking	Peaking
	Balakot			Baseload	Baseload	Baseload	Baseload
	Patrind	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
Upper Jhelum	Wular					Baseload	Baseload
	Lower Jhelum	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Uri I	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Uri II	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Chakothi-Hattian					Baseload	Baseload

Subbasin	HPP	Existing and under-construction		Committed		Planned	
		Agreed management	High management	Agreed management	High management	Agreed management	High management
Upper Jhelum	Kohala	Peaking EFlow release (30 m³/s)	Baseload EFlow release (30 m³/s)	Peaking EFlow release (30 m³/s)	Baseload EFlow release (30 m³/s)	Peaking EFlow release (30 m³/s)	Baseload EFlow release (30 m³/s)
Lower Jhelum	Mahl			Peaking	Baseload	Peaking	Baseload
	Azad-Pattan			Baseload	Baseload	Baseload	Baseload
	Karot	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
Poonch	Parnai			Baseload	Baseload	Baseload	Baseload
	Sehra			Baseload	Baseload	Baseload	Baseload
	Gulpur	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload

Table G-3: Protection Levels Applied for River Reach Represented by Each EFlow Site

River reach represented by			Agreed management	High management
Neelum	1	Line of Control	Pro 1	Pro 1
	2	Surgun Nullah	Pro 1	Pro 1
	3	Dudhnial	Pro 1	Pro 1
	4	Athmuqam	Pro 1	Pro 1
	5	Jagran Nullah	Pro 1	Pro 1
	6	Nauseri (o)	Business as usual	Pro 2
	7	Panjgiran	Business as usual	Pro 2
	8	Patikka Nullah	Business as usual	Pro 2
	9	Dhanni	Business as usual	Pro 2
	10	Muzaffarabad	Business as usual	Pro 2
Upper Jhelum	11	Upstream KHPP	Pro 3	Pro 3
	12	Subrey	Pro 3	Pro 3
Kunhar	13	Khanian	Business as usual	Pro 2
	14	Paksair	Business as usual	Pro 2
Lower Jhelum	15	Ambor-5	Pro 3	Pro 3
	16	Kohala-6	Business as usual	Pro 2
	17	Mahl Nullah	Business as usual	Pro 3
	18	Mahl DS	Business as usual	Pro 2
	19	Azad Pattan	Business as usual	Pro 2
	20	Kahuta Nullah	Pro 2	Pro 2
	21	Hollar-7	Pro 2	Pro 2
Poonch	22	Kallar Bridge	Pro 2	Pro 3
	23	Borali Bridge	Pro 2	Pro 3
	24	Gulpur Bridge	Pro 2	Pro 3
	25	Billiporian Bridge	Pro 2	Pro 3

Note: Pro 1 = 2013 pressures fixed for the next 30 years; Pro 2 = 2013 pressures halved over the next five years and then stable at that level for the next 25 years; Pro 3 = reduce 2015 levels of non-flow-related pressures by 90 percent, that is, decline in pressures (relative to 2015) over time (only applied for the Kohala HPP).

For each scenario, predicted changes in the river ecosystem are presented as a change in overall ecosystem integrity relative to baseline (BASE 2012 Pro 1) for the river reach represented by each EFlow site. Ecosystem integrity is classified using categories A to F (**Table G-4**).

The overall ecosystem integrity for each EFlow reach associated with each scenario is summarized in **Table G-5** and shown in **Figure G-3**.

The DSS provides estimated mean percentage change from baseline in the abundance, area, or concentration of the indicators (these are tabulated in **Annex G.A**). To calculate integrity, the absolute predicted score for each indicator was assigned a positive (+) or negative (–) value to show whether an increase in that indicator would represent a move toward or away from the natural condition of the river. Discipline integrity ratings were then calculated from the abundance changes. The integrity ratings for each discipline were then combined to provide an overall ecosystem integrity (Brown et al. 2008).

Table G-4: Ecological Integrity Ratings

Ecological category	Corresponding DRIFT integrity	Description of the habitat
A	>−0.25	Unmodified: the habitat is still in a natural condition.
B	>−0.75	Slightly modified: a small change in natural habitats and biota has taken place, but the ecosystem functions have essentially remained the same.
C	>−1.5	Moderately modified: loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	>−2.5	Largely modified: a large loss of natural habitat, biota, and basic ecosystem functions has occurred.
E	>−3.5	Seriously modified: the loss of natural habitat, biota, and basic ecosystem functions is extensive.
F	<−3.5	Critically/extremely modified: the system has been critically modified with an almost complete loss of natural habitat and biota; in the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

Source: Kleynhans 1996

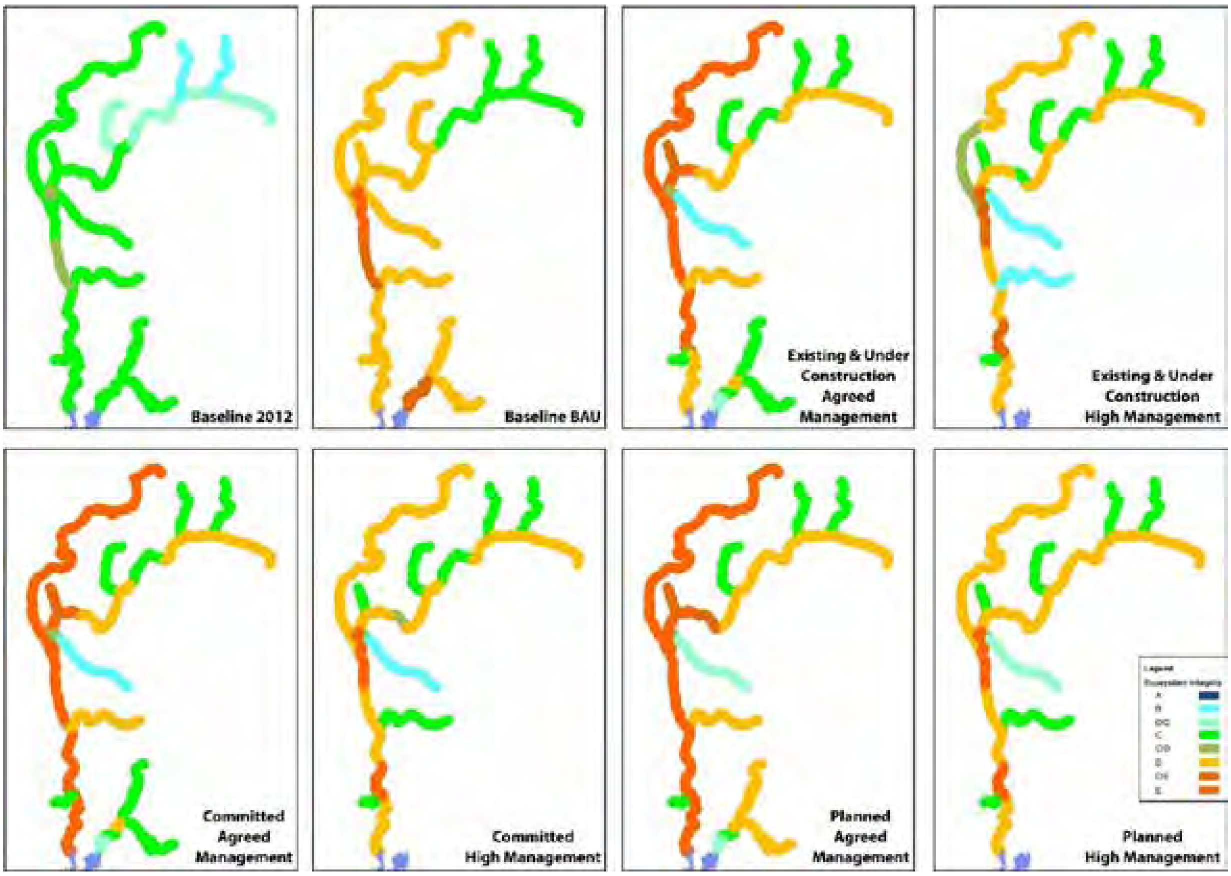
Table G-5: Overall Ecosystem Integrity for Each EFlow Reach of Each Scenario

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) Business As Usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Neelum	Line of Control	B/C	C	D	D	D	D	D	D	D	D
	Surgun Nullah	B	C	C	C	C	C	C	C	C	C
	Dudhnial	B/C	C	C	C	C	C/D	C	C	D	D
	Athmuqam	C	D	D	D	D	D	D	D	D	D
	Jagran Nullah	B/C	D	C	C	C	C	C	C	C	C
	Nauseri	C	D	D	C	C	C/D	D	C/D	D/E	D
	Panjgiran	C	D	E	D	D/E	D	E	D	E	D
	Pattika Nullah	C	D	D/E	C	C/D	C/D	D/E	C	D/E	C
	Dhanni	C	D	E	C	D/E	D	E	D	E	D
	Muzaffarabad	D	E	E	E	E	E	E	E	E	E
Upper Jhelum	Upstream Kohala HPP	C	D	B	B	B/C	B/C	B	B	B/C	B/C
	Subrey	C	D	C/D	C	D	C/D	C/D	C	C/D	C/D
Kunhar	Khanian	C	D	E	D	D	D	E	D	E	D
	Paksair	C	D	E	C/D	D	D	E	D	E	D

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) Business As Usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Lower Jhelum	Ambor	C/D	E	E	D/E	E	E	E	E	E	E
	Kohala	C/D	D/E	E	D	D/E	D/E	E	D	E	D
	Mahl Nullah	C	D	D	B	B/C	B/C	D	C	D	C
	Mahl DS	C	D	E	D	D	D	E	D	E	D
	Azad Pattan	C	D	E	D/E	E	E	E	E	E	E
	Kahuta Nullah	C	D	C	C	C	C	C	C	C	C
	Hollar	C	D	D	D	D	D	E	D	E	D
Poonch	Kallar Bridge	C	D	C	Not run			C	Not run	D	Not run
	Borali Bridge	C	D/E	D				D		D	
	Gulpur Bridge	C	D/E	C				C		C	
	Billiporian Bridge	C	D/E	B/C				B/C		B/C	

Note: SF-4 = April sediment flush; SF-8 = August sediment flush

Figure G-3: Predicted Overall River Condition for Scenarios Tested Using DRIFT



Note: See **Figure 1** in **Section 1** of the main report for a detailed map showing the rivers and their names.

Results

Overall, the gradual increase in the number of hydropower projects in the Jhelum-Poonch Basin will be accompanied by:

- A decline in sand and gravel availability in the rivers. This may be partially offset by the flushing of sand-sized sediments, but gravels cannot be flushed from the reservoirs for many years.
- An increase in the availability of cobble and boulders. This is mainly because they will become exposed as sands and gravels are eroded and not replaced because they are trapped in upstream reservoirs.
- This effect is unlikely to persist for a great distance downstream of any single HPP, particularly in the upper parts of the basin, because of the high sediment supply from the hillslopes (landslides). It may be more problematic downstream, where less sediment is supplied by the slopes and the cumulative impacts of many HPPs has a greater effect on supply.
- Reduced habitat diversity directly linked to lower sediment supply and increased erosion. This is likely to affect breeding habitats, as many spawning fish tend to favor gravel habitats.
- Changes in habitats and the knock-on effects on other aspects of the river ecosystem, such as downstream riparian vegetation and macroinvertebrates that provide much of the fish food, will reduce fish abundance.
- Sediment flushing will unlikely alleviate the negative impacts because it results in large and simultaneous supplies of sediments that are difficult to sort or move downstream. The net effect is often localized smothering of habitats rather than a reset to more natural sediment-supply levels in a whole river reach.
- The large migratory fish species, such as the brown trout and golden mahseer, will be particularly hard hit as the insurmountable HPP weirs will lead to a progressive decline in their home range.
- It is worth noting that the proposed HPPs all have extensive reservoirs, which will result in deeper, lake-like habitat unsuitable for colonization by most river species. This will significantly transform the nature of the aquatic ecosystems in the Jhelum-Poonch Basin.

The fish-integrity results, presented separately in **Table G-6**, show several interesting effects, such as the impact of upstream HPPs on rivers downstream of other HPPs. For instance, at Hollar in Lower Jhelum River, fish integrity under the agreed-management scenario is an "E" even through the agreed management is Protection Level 2 because it is expected that peaking from the Neelum-Jhelum and Kohala HPPs will not be attenuated by the Karot reservoir, leading to wide flow fluctuations in the downstream river daily. However, under high management, both HPPs will operate as baseload plants and fish integrity at Hollar is expected to improve to a "D" category. Thus, the efforts of management at the Kishanganga HPP in protecting the downstream river may be contradicted by operation of upstream HPPs. Other knock-on effects are also evident; for example, sediment flushing will negatively affect fish in the mainstem and have a knock-on effect on fish integrity in Kahuta Nullah as some species will migrate from the main river to the nullah.

Table G-6: Fish Integrity for Each EFlow Reach of Each Scenario

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) business as usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Neelum	Line of Control	B	D	D	D	E	E	D	D	D	D
	Surgun Nullah	B	C	B	B	C	B/C	B/C	B/C	B/C	B/C
	Dudhnial	B	D	C	C	E	E	C/D	C	D	D
	Athmuqam	C	D	D	D	E	E	D	D	D/E	D/E
	Jagran Nullah	B	D	C	B	C	C	C	B	C	C
	Nauseri	C	D/E	E	C	E	E	E	C	E	C
	Panjgiran	C	D/E	E	E	E	E	E	E	E	E
	Pattika Nullah	C	E	E	E	E	E	E	E	E	E
	Dhanni	C	E	E	E	E	E	E	E	E	E
	Muzaffarabad	D	E	E	E	E	E	E	E	E	E

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) business as usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Upper Jhelum	Upstream Kohala HPP	C	E	A	A	B	B	A	A	A	A
	Subrey	C	E	D	D	E	E	D	D	D	D
Kunhar	Khanian	C	E	E	C	E	E	E	C/D	E	C/D
	Paksair	C	E	E	C/D	E	E	E	D	E	D
Lower Jhelum	Ambor	D	E	E	E	E	E	E	E	E	E
	Kohala	D	E	E	D	E	E	E	E	E	E
	Mahl Nullah	C	E	E	A	A	A	E	A/B	E	A/B
	Mahl DS	C/D	E	E	D	E	E	E	E	E	E
	Azad Pattan	C	E	E	C/D	E	E	E	D/E	E	D/E
	Kahuta Nullah	C	E	D	B	D	C/D	D	B/C	D	B/C
	Hollar	C	E	E	D	E	E	E	D	E	D
Poonch	Kallar Bridge	D	E/F	C				C		D	
	Borali Bridge	D	F	F				F		F	
	Gulpur Bridge	D	F	B		Not run		B	Not run	B	Not run
	Billiporian Bridge	D	F	A/B				A/B		A	

Note: SF-4 = April sediment flush; SF-8 = August sediment flush.

The results are discussed in terms of the main subbasins, namely:

- The Neelum River upstream of the confluence with the Jhelum River
- The Kunhar River
- The Upper Jhelum River from the Line of Control to the confluence with the Neelum River
- The Lower Jhelum River from the confluence with the Neelum River to the Mangla Reservoir
- The Poonch River

The outcomes of the scenarios and the reasons behind are broadly consistent across the different versions of the DRIFT DSS. Nonetheless, the 2018 version (this version) does return slightly different results from those of the 2016 version. The differences are related to the updates to the DSS explained in **Section G.A.3** of **Annex G.A** and changes in the response curves of the geomorphological indicator to incorporate information from the sediment audit (**Section G.A.2** of **Annex G.A**). For the most part, these are also consistent with the previous version. The single exception is the direction of change predicted for cobble and boulder bars. The explanations in the 2016 DRIFT DSS mentions that sand overlies cobbles, meaning when sand is lost from the system, the result—at least in the short-term—would increase the exposure of the cobble bars. This is how the channel will armor: It will first lose sand and gravel to expose cobbles; over time, because the cobbles are trapped in the HPPs, their amount in the system will fall and the cobble bars themselves will also be washed away. However, it is assumed that this eventuality will take longer than the 30 years modelled in the DSS. The cumulative impacts on the aquatic ecological resources can be summarized as follows:

- Most of the impacts in the **Neelum River** occur under the scenario of existing and under-construction HPPs, such as the Kohala and Neelum-Jhelum HPPs. Adding the Athmuqam HPP (committed) and Dudhnial HPP (planned) will lead to incremental impacts on key indicators and a slight decrease in the overall condition of the river downstream of these HPPs than under the existing and under-construction scenario. This is partly because the Athmuqam and Dudhnial HPPs will operate as true run-of-river baseload plants—that is, hourly flow entering the impoundment equals released flow—and have little influence on downstream flows. They will act as barriers to fish migration and sediment, but their influence is expected to be offset by the large tributaries entering the Neelum River upstream and downstream of these two HPPs. The lack of change in overall integrity at Muzaffarabad under high management hides the fact that there is a noticeable reduction in nutrient concentration and better water quality, which will have a knock-on effect on macroinvertebrates and fish.

- The results for the **Kunhar River** mainly reflect the drop in condition under the business-as-usual scenario and the barrier effects on fish (mainly Alwan snow trout) from the Patrind, Balakot, and Suki Kinari HPPs. The individual indicator results show slight incremental impacts after adding the Balakot and Suki Kinari HPPs to the impacts of the Patrind HPP. As is the case for the Neelum River, the high-management scenario results in a more favorable overall integrity because of improved protection levels against non-flow-related impacts in the subbasin.
- The **Upper Jhelum River** is affected by the Kishanganga and Kohala HPPs in the existing and under-construction scenario. In this scenario, the reaches upstream of Kohala and at Subrey are modelled under Protection Level 3 under agreed management, which prohibits any use of the river resources. This, combined with the enhanced dry-season flows supplied by the Kishanganga HPP, improves the integrity of the river upstream of Kohala HPP. The river downstream of the Kohala HPP, however, is affected by major changes to the minimum dry-season discharge and the onset and duration of the wet and dry seasons. With the Chakothi-Hattian HPP (modelled as a baseload plant with some sediment flushing) in place, the reaches upstream of Kohala HPP deteriorates slightly mainly because of its barrier effect on fish migration and sediment supply. The high management without sediment flushing does not yield major changes in the predicted outcomes. Flushing sediment down the Jhelum River, however, is expected to have negative consequences for the ecosystem, primarily fish. This is mainly because when sediments are periodically flushed from the reservoir, periods of low sediment loads could be interspersed with intermittent periods of heavy, possibly anoxic sediments moving downstream—neither is natural and together they can cause extreme conditions. In whichever way the channel adjustments play out, downstream riverine habitats and biota will be affected, perhaps through lack of oxygen to support life or sediments clogging the gills of macroinvertebrates and fish as well as important habitats including spawning grounds.
- The existing and under-construction HPPs on the **Lower Jhelum River** include Kishanganga, Neelum-Jhelum (tailrace outlet), Patrind, Karot, and Kohala (tailrace outlet). In this scenario, the condition of the Mahl's downstream reach is slightly enhanced by its proximity to the Mahl Nullah. The Kohala, downstream Mahl, and Azad Pattan reaches are heavily affected by the fluctuating daily flows in the dry and transitional seasons as a result of peaking power generation at the Neelum-Jhelum and Kohala HPPs. These effects might extend to the Azad Pattan and Kohala reaches but are not currently captured by the DRIFT DSS. The benefit to all three sites will increase if the Mahl Nullah is given greater protection. The impacts for the existing and under-construction scenario can also be reduced by running the Neelum-Jhelum and Kohala HPPs as baseload plants. Although the committed Mahl and Azad Pattan HPPs are both modeled as baseload plants, they will peak involuntarily as a result of the peaking effects from the Neelum-Jhelum and Kohala HPPs. Fish and sediments in these reaches are also heavily affected by the barrier effect of the weirs associated with the Mahl and Azad Pattan HPPs.
- The first two scenarios in the **Poonch River** include only the Gulpur HPP and reflect the operating rules and protection provisions already agreed or implemented for this HPP. The planned scenario, which includes the Sehra HPP, is expected to lead to a slight decrease in the condition of the Poonch River upstream of the Gulpur HPP. This minor change in overall integrity, however, belies a reduction of 20 to 30 percent decline in species such as the Alwan snow trout and Pakistani labeo.

Summary and Conclusion

This report covers more technical DSS adjustments done to improve data handling in the Jhelum-Poonch Basin-Wide DRIFT DSS, which was created in 2016 using the individual DSSs developed in EFlow studies for the Gulpur, Karot, Kishanganga, Kohala, and Neelum-Jhelum HPPs.

The scenarios presented here illustrate the cumulative impacts associated with progressive development of HPPs on the mainstem rivers of the Jhelum-Poonch Basin and the possibilities for mitigating these impacts through management and operation (peaking versus baseload power production and sediment flushing). They excluded developments on the nullahs as it was not possible to source the hydrological data needed to model these in the time frame required. The scenarios do, however, include management options for the nullah groups.

At the current level of site-specific data and expert consideration given to the response curves in the DSS, it would be unwise to extend its functionality further following this phase. The DSS would benefit from more detailed attention to hydraulics and hydrodynamics as well as a review of the response curves (particularly those for fish) based on monitoring data collected after the commissioning of the Neelum-Jhelum, Patrind, Gulpur, and other planned HPPs.

The summary results of ecosystem and fish integrity presented in the main body of this report tell a forbidding story on biodiversity protection in the Jhelum-Poonch Basin if the full suite of planned HPPs is implemented. More detailed indicator results in **Annex G.A** of this **Annex G** show that it will be extremely difficult, if not impossible, to prevent the loss of fish species under the committed and planned scenarios.

The response curves underpinning the DSS are the result of considerable discussion and review of international literature. They represent the best estimate of the relationships driving the system given current knowledge. They are documented and motivated clearly in the DRIFT DSS, which can be used as a foundation on which to build future work to add knowledge on the river ecosystem of the Jhelum-Poonch Basin. Further tests can be done on relationships deemed most influential or least known, such as fish-migration patterns following the fragmentation of the main stem and subsequent use of the nullahs as well as ecosystem responses to the releases of peaking power.

G.1.3 Impact on Subsistence and Recreational Fishing

As described in **Section 4** of the main report, subsistence fishing is limited and fish is not an important or significant part of local diet. Recreational fishing, however, is important in the Poonch River (mainly the mahseer) and the Neelum River, where the brown trout is found. Communities have shifted to farming rainbow trout in the Kunhar River, so angling of this fish is no longer of significance. In the Poonch River, a community-based program for recreational fishing has been approved by the government and is being implemented in collaboration with the Himalayan Wildlife Foundation. Such initiatives can be replicated in the Neelum River in the areas upstream of Dudhnial, where the brown trout is found.

G.2 Impacts of Reservoirs on Fish Species of Concern

DRIFT modelling described in the previous section predicts the impact of flow changes on the ecological resources and integrity in the area of management. However, the model does not include impacts from inundation or creation of reservoirs. These impacts are discussed separately in this section.

G.2.1 General Impacts of Reservoirs on the Environment and Ecosystems

Reservoir formation in hydropower projects often leads to irreversible and essentially negative environmental changes. Artificial lakes profoundly alter the natural functioning of the entire ecosystem, ranging from changing flow regimes as well as water temperature and chemistry, modifying algal and macroinvertebrate communities, disrupting resident and migratory fish communities, altering channel geomorphology and sediment transport, and affecting the abundance and diversity of physical habitats (Manatunge, Nakayama, and Priyadarshana 2001). These are briefly described below.

Effects of the Barrier Caused by the Dam

- The reservoir causes the suspended particles to settle, thereby limiting its storage capacity and the flow of sediments downstream, which hampers agricultural activities on floodplains and cause scouring of the riverbed downstream owing to reduced nutrient-rich sediments.
- If sediments are periodically flushed from the reservoir, then periods of low sediment loads would be interspersed with intermittent periods of heavy (possibly anoxic) sediments moving downstream—this could cause extreme conditions with negative impacts for the fish fauna, particularly downstream of the dam (Morris and Fan 1998).
- Disrupt migration of fish species along the river.
- Increase amphibian and bird populations.
- Entrapped nutrients in the reservoir can lead to high eutrophication and subsequent excessive growth of aquatic weeds and low dissolved oxygen, which can be detrimental to aquatic ecological resources.
- Water quality can be affected by decomposition of flora and fauna as well as pollution from increased human activity, including agriculture, recreation, and industries (Manatunge, Nakayama, and Priyadarshana 2001).

Alteration of the River's Natural Flow Patterns

Impoundment by the reservoir will boost the water velocity immediately below the dam. This will reduce peak river flows, increase low flows, and eliminate the annual discharge cycle previously governed primarily by climatic factors. This has many implications for the environment (Manatunge, Nakayama, and Priyadarshana 2001).

- Impacts on water quantity to maintain downstream biological activity, floral and faunal community downstream, and loss of wetlands
- Increased scouring and degradation of riverbeds downstream as well as coastal erosion
- Changes in water quality downstream including physical parameters
- Narrowing of river channels, which will become overrun with vegetation
- Less natural submergence for flood-recession agriculture as well as reduction in groundwater recharge and in removal of parasites by natural flooding

Indirect Effects of Reservoirs

Some negative effects of reservoirs include the following:

- Terrestrial habitat loss from inundation
- Environment degradation from increased human activities such as intensive agriculture, industries, and increased pressure on lands
- Changes in water tables—higher around the reservoir and lower downstream—and frequent landslides

G.2.2
Impact of Reservoirs on Fish Fauna in the Area of Management

Fish populations are highly dependent on the aquatic habitats supporting their biological functions. Habitat fragmentation caused by HPP reservoirs will reduce the quality and quantity of suitable feeding and spawning grounds for both migratory and resident fish species. Loss of breeding habitats and nurseries will lead to a decline in the populations of certain species, with the possibility of extirpation from the watershed (Rice, Greenwood, and Joyce 2001). Migratory fish are more likely to be affected since they require discrete environmental conditions for the main phases of their life cycle, including reproduction, production of juveniles, growth, and sexual maturation. Construction of a hydropower project, particularly multiple ones on the same river, may result in limitations to their movement and a decline in population numbers, reduction in species diversity, and change in species dominance or natural assemblages (Rice et al. 2008)

Changes in the physical, chemical, thermal, and geomorphological profile of a river caused by the creation of a dam reservoir can often lead to a reduction in fish diversity, change of species dominance or natural assemblies, and impairment for migratory species to fulfill their life cycle. This section outlines the impact of hydropower project reservoirs on fish species of concern in the area of management.

In the area of management, most fish species such as Garra, Glyptosternum, Puntius, Glyptothorax, Shistura, and Triplophysa do not like lacustrine conditions and will likely disappear from the reservoirs. Schizothorax sp., particularly the Alwan snow trout, is also likely to abruptly reduce in numbers and become rare. The mahseer is not known to thrive in lake-like conditions. Only the Indus garua finds reservoir conditions favorable and displays colonization in the reservoirs. The expected impacts on fish are summarized below:

- The three endemic fish species—the Kashmir catfish, Kashmir hillstream loach, and Nalbant's loach—will disappear from the reservoirs as they prefer flowing water and cannot survive in lacustrine conditions.
- The mahseer requires flowing water for breeding and feeding. While some mahseer are likely to survive in reservoirs, those reservoirs with fine clayey bed sediments (devoid of gravel or cobbles) and a very low current will not provide a preferred habitat for these fish.
- The population of the Alwan snow trout will dramatically decline in reservoirs as the barrier created by the dam will hinder its migratory patterns.
- The Pakistani labeo requires a lotic river habitat for breeding and its population is likely to decline dramatically in reservoirs.
- The Indus garua is an exception as it can adapt to a lentic environment and has better tolerance of temperature variations than other migratory fish species. A loss in its population due to the barrier created by HPPs will likely be offset by an increased availability of habitats in reservoirs.
- The sucker head is adapted to river conditions. It is not known to breed or feed in reservoirs, so its population will be very small.
- The twin-banded loach, Himalayan catfish, and Chirruh snow trout will most likely be completely wiped out from the reservoirs.
- The Gora chela can survive in reservoirs, but its natural population is restricted to the Mangla Reservoir and the lower reaches of the Jhelum River. It will be absent from the reservoirs of HPPs in the upper reaches of the Jhelum.

A shift in habitat from riverine to lake will open gates for project owners to stock and grow fish for recreational purposes. The slow-moving waters and temperature changes caused by reservoirs can provide improved environments for warmwater fish, such as exotic commercial carp.

Introduction of exotics such as the grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), common carp, and Mozambique tilapia (*Oreochromis mossambicus*) have already permanently altered the river ecology both upstream and downstream of the Mangla Reservoir. Biodiversity will decrease because of the construction of dams sequentially upstream into the Jhelum River, which will further extend the lake ecosystems into the basin. Fish like the Pakistani labeo and Indus garua, which mainly live in downstream sections of the river, will not be able to swim upstream of the dams because of the construction of the Azad Pattan, Karot, Kohala, and Mahl HPPs. Similarly, fish that mainly breed in warmer waters in tributaries and rivers downstream of the Line of Control, such as the mahseer, Indus garua, and Pakistan labeo, will be unable to travel to the upper reaches of the Jhelum River. The introduction of non-native or introduced fish species in the reservoirs of the planned HPPs can further complicate the situation because of competition for food and resources.

G.3
Impact on Terrestrial Ecology

The construction and operation of hydropower projects in the area of management are likely to impact terrestrial ecological resources because of:

- Habitat loss due to the development of project infrastructure, construction-related activities, and operation of HPPs, although these impacts are restricted to the project sites and vicinity
- Construction and operation of electricity-transmission lines from the HPPs to the grid and onward to consumers

G.3.1
Impacts at Project Site and Vicinity

Hydropower projects modify the river's flow regime, thus primarily affecting aquatic ecological resources. Most HPPs are the run-of-river type and do not involve loss or inundation of large terrestrial areas. However, each project affects the terrestrial ecology in its vicinity as a result of habitat loss and activities related to construction and operation.

Terrestrial Habitat Loss

Site clearance and construction of project infrastructures such as the powerhouses, dams, and the inlets and outlets of the tunnels will result in immediate and direct modification of land and loss of terrestrial habitats. This will lead to loss of plants and displacement of animals in the area. Land within the footprint of specific project facilities and its ancillaries will be permanently modified, but the loss will be less severe in the areas lying adjacent to and immediately outside the project facilities.

Once a project begins operations, some terrestrial areas will become submerged because of the formation of a reservoir upstream of the dams. The submerged terrestrial habitat will be converted into an aquatic habitat. The habitat loss and fragmentation resulting from project infrastructure will lead to displacement of terrestrial species.

Impacts on Terrestrial Biodiversity from Construction and Operation

Construction and operation of HPP infrastructures, such as powerhouses, dams, and tunnels, will cause disturbances to the terrestrial floral and faunal within the impact zone of project facilities because of blasting, noise, vibrations, illumination, and possible introduction of alien species. Vehicles and machinery, spillage of fuels or chemicals, emissions, and noise will aggravate pollution. Vehicle movements will increase the risk of vehicle collision with wildlife. Biodiversity may also be disturbed because of loss of soil productivity caused by contamination from oil spills and leakages from project vehicles and machinery, uncontrolled discharge of wastewater, and stormwater runoff from the project site.

As plant operation will be continuous, the disturbances will affect both diurnal and nocturnal wildlife. These sensory disturbances and habitat fragmentation may reduce species abundance and possibly diversity within an impact zone of each hydropower project in the area of management. The spatial and temporal distribution of species may also be affected. Illegal hunting, fishing, and tree-cutting may also increase as a result of an influx of project staff and contractors.

G.3.2
Impacts on Terrestrial Biodiversity from Transmission Lines

A transmission line is a pair of electrical conductors carrying an electrical signal from one place to another. Several transmission lines will be laid in the area of management to transmit electricity from the newly constructed hydropower projects to the grid and onward to consumers. This section provides an overview of the impact of these transmission lines on the terrestrial ecological resources identified in the previous section.

Overview of Transmission-Line Impacts

The operation of transmission lines has not been associated with significant negative environmental impacts. However, the initial construction phase of the towers (pylons) and transmission lines may affect terrestrial biodiversity mainly because of site preparation, access-road construction, vehicle movement, reinforcing cement-concrete foundations, and erection of towers.

Construction-phase impacts on terrestrial habitats are usually temporary and localized, other than the permanent changes they might introduce in the local landscape and land use (National Environment Commission 2012). Small mammals and herpetofauna are affected by construction dust and noise. If the waste generated during construction is not disposed of adequately, this may lead to more serious ecological impacts, including pollution of waterbodies in the vicinity. The significance of the impact will depend on the scale or magnitude of construction and the sensitivity of the ecological receptors in the vicinity.

Operation-phase impacts on terrestrial ecological resources are usually minor, except on avifauna, which are often harmed by collision and electrocution as a result of power or transmission-line operation.

The likely impacts of transmission lines on terrestrial ecological resources are summarized below:

Vegetation

- Vegetation may be removed or damaged in order to erect the pylons of transmission lines, leading to localized habitat degradation and decline.
- Habitat disturbance caused by construction may increase the spread of alien invasive species.
- Dust produced during construction may coat the leaves of surrounding plants, hindering photosynthesis and causing detrimental effects on plant health (National Environment Commission 2012).
- Fuel fumes and gases from construction may affect plant species, particularly smaller and sensitive herbaceous plant varieties.

Mammals

- Digging, drilling, and other construction activities can degrade and disturb habitat, causing death and injury of animals, particularly small burrowing mammals.
- A higher volume of vehicular traffic during construction may increase the risk of collision with medium and large mammals, resulting in mortality of individuals.
- Inadequate waste disposal may attract scavengers and increase carnivore-human encounters.
- Flying mammals, such as bats, are at risk of colliding with transmission wires or pylons and suffering injuries or death
- Noise, light, and electromagnetic fields from transmission pylons and wires may affect the behavior of wild mammals.

Birds

- Construction noise, dust, and habitat disturbances will likely affect the circadian pattern of birds and disturb their breeding, foraging, and roosting (AMEC 2015).
- Bird nests may be removed when trees are cut to construct pylons.
- Flying birds may be electrocuted when they come between two energized components or an energized and grounded component of the pole structure (Lehman, Kennedy, and Savidge 2007). A bird with a wingspan greater than 110 cm, perched on the cross arm, can touch two conductors simultaneously and get electrocuted. Species such as vultures, eagles, hawks, storks, and owls are most commonly killed through electrocution.
- Collision with power lines is an important cause of death for some species of birds (Prinsen et al. 2011). These avian collisions can occur in large numbers if the transmission lines are located within daily flyways or migration corridors, or if bird groups are traveling at night or during low-light conditions. The birds may die as a result of the initial collision or subsequent impact with the ground.

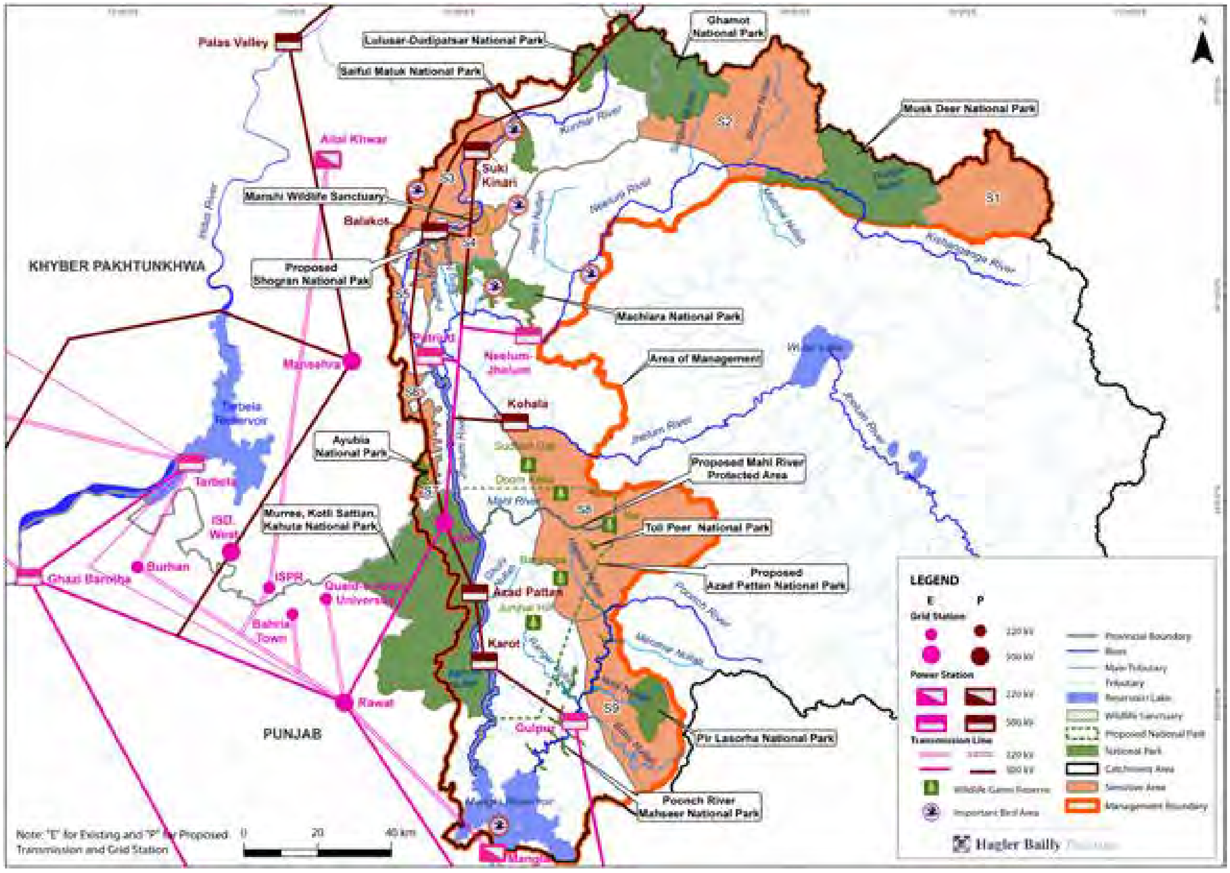
Herpetofauna

- Digging, drilling, and other construction activities can degrade and disturb habitats, causing death and injury of herpetofauna, particularly the burrowing types.

Planned Transmission Lines and Grid Stations

Figure G-4 shows a map of the existing and planned transmission lines overlaid on identified sensitive and protected areas (**Section 3.2.2** of Main report) in the area of management based on information taken from "National Transmission and Despatch Company (NTDC), Pakistan, Existing and Proposed 500/220 kV stations and transmission lines—Grid Map 2020."

Figure G-4: Existing and Planned Transmission Lines in the Area of Management until 2020



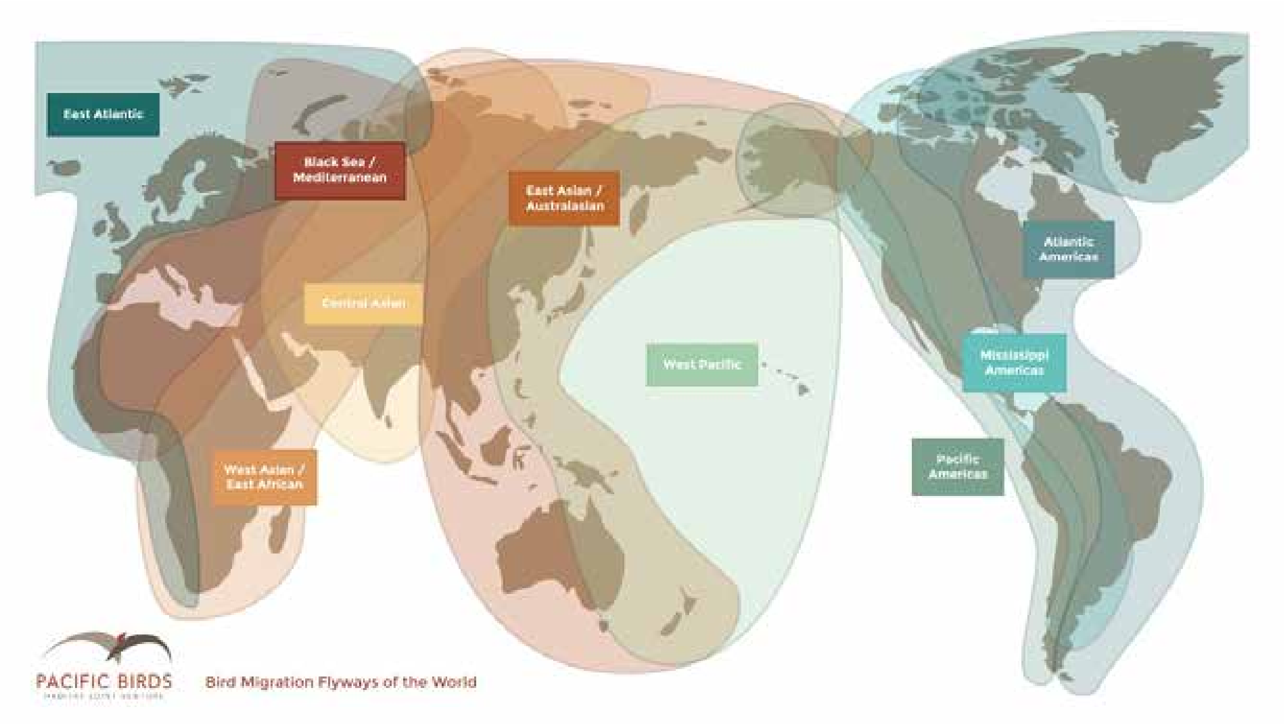
Impacts of Transmission Lines in the Area of Management

Impacts from the construction and operation of transmission lines on terrestrial biodiversity in the area of management, including sensitive and protected areas identified in **Section 3.2.2** of Main report, are outlined below:

- Vegetation species will reduce where pylons are erected, leading to localized habitat degradation. The impact of vegetation removal will be high in AJK and some parts of KP, where large tree species (*Pinus wallichiana*, *Betula utilis*, *Cedrus deodar*a, and *Pinus roxburghii*) provide quality habitats, breeding sites, and shelters for threatened wildlife species. Sensitive areas S3, S4, S5, S6, and S7 are most vulnerable to this impact.
- Alien-invasive species have been reported from the entire area of management. Habitat disturbance as a result of construction may increase the spread of these species (IFC 2007).
- Construction of pylons will disturb small mammals and herpetofauna, particularly in sensitive areas S3, S4, S5, S6, and S7.
- Sensitive and protected areas in the area of management provide habitats for several large mammals of conservation importance, including the musk deer (*Moschus chrysogaster*), snow leopard (*Panthera uncia*), common leopard (*Panthera pardus*), Asiatic black bear (*Ursus thibetinus*), and brown bear (*Ursus arctos*). Construction-related noise, vibrations, gaseous emissions, and habitat disturbances will drive away these medium to large mammals.
- Birds are most vulnerable to the operational impacts of transmission lines because of possible collision and electrocution. This is of particular concern in the close vicinity of important bird areas, particularly in sensitive areas S3, S4, and S9. The large raptor species such as the white-rumped vulture, Egyptian vulture, Himalayan griffon vulture, and steppe eagle are most vulnerable to this impact.
- Pakistan is on the Indus Flyway, or International Migratory Bird Route (**Figure G-5**). A significant number of migratory birds visit Pakistan from Europe, Central Asian states, and India, spending winter in various wetlands and deserts, including

the high Himalayas, coastal mangroves, and mud flats in the Indus Delta. They return to their native lands at the advent of spring. Based on regular bird counts at different Pakistani wetlands, an estimated 700,000 to 1.2 million birds arrive in Pakistan through the Indus Flyway every year (MoE 2012). Several migratory birds (cranes, ducks, geese, grebes, storks, and ibis) have been reported from the area of management. They are at risk of collision with and electrocution by transmission lines, particularly in close vicinity of the Machiara National Park near Muzaffarabad, important bird areas, and sensitive areas S3, S4, and S9.

Figure G-5: Asian Migratory Bird Flyways



Source: https://pacificbirds.org/birds-migration/the-flyways/

G.A.1 Introduction

Basin-Wide Studies in the Jhelum-Poonch Basin for Sustainable Hydropower aims to understand the cumulative impacts of hydropower development in the basin and develop a biodiversity strategy to address environmental and social issues. Southern Waters, in association with L. Koehnken Pty. Ltd. (Southern Waters/Koehnken) were assigned several tasks in the project, including:

- A sediment audit of the basin that generated a sediment balance and provided insights on how HPP development could change sediment in the basin. The analysis addressed questions such as: Which reservoirs will trap bedload sediments? When will HPPs attain equilibrium of sediment load? How will sediment patterns change above and below each HPP?
- Updates to the consolidated DRIFT DSS for the Jhelum-Poonch Basin, including:
  - ¤ A review of sediment handling and the sediment response curves in the DRIFT DSS based on the understanding gained from the sediment audit
  - ¤ Generation of sediment input values for baseline and development scenarios based on the understanding gained from the sediment audit
  - ¤ Adjustments to the layout of the DSS to incorporate updates to sediment input data
  - ¤ Updating the hydrological data using timeseries provided by Hagler Bailly Pakistan (HBP)
- A training and testing workshop for the DRIFT DSS review based on an evaluation of the DSS predictions for a series of hypothetical "testing" scenarios
- Analysis using the updated DRIFT-DSS of around 10 scenarios encompassing individual changes in hydropower developments, such as flow regime, sediments, basin management, and fish migration

Study Area

The study area for this project is the area of management including the subbasins of the Jhelum-Poonch Basin falling within the territory of Pakistan. The subbasins are named after the rivers in this review (**Figure G.A.1**), for example, upper Jhelum, middle Jhelum, lower Jhelum, Neelum, Kunhar, and Poonch.

Figure G.A.1: Map of the Area Included in This Review with River Basin Names

A list of existing and under-construction, committed, and planned HPPs is presented in **Table G.A.1**. The Jhelum and Poonch rivers both flow into Lake Mangla, which flooded their confluence when created by the Mangla Dam, but the two catchments are otherwise regarded as independent. Within the Jhelum Basin, the rivers targeted for development include the middle and lower Jhelum, the Neelum, and the Kunhar rivers. In the Poonch Basin, the mainstem is targeted for HPP development.

Table G.A.1: Existing, Under Construction, Committed, or Planned HPPs in the Jhelum-Poonch Basin, Upstream of the Mangla Dam

Status	#	HPP	Capacity	River	Notes
Existing or under construction	1	Kishanganga	330 MW	Neelum	About 12 km upstream of the Line of Control; will divert water to the upper Jhelum River upstream of Muzaffarabad
	2	Neelum-Jhelum	999 MW	Neelum	At Nauseri; will divert water to the lower Jhelum River about 29 km downstream of Muzaffarabad
	3	Patrind	147 MW	Kunhar	Just upstream of its confluence with the Jhelum River
	4	Karot	720 MW	Jhelum	Near Hollar Bridge
	5	Lower Jhelum	105 MW	Jhelum	Upstream of Uri I in Indian-administered Kashmir
	6	Uri I	480 MW	Jhelum	In Indian-administered Kashmir
	7	Uri II	240 MW	Jhelum	In Indian-administered Kashmir
	8	Kohala	1100 MW	Jhelum	Upstream of Muzaffarabad near Siran Village; will divert water to the Jhelum River about 40 km downstream of Muzaffarabad
	9	Gulpur	102 MW	Poonch	Near Kotli
	10	Parnai	37 MW	Poonch	Just upstream of the Line of Control; will divert water to the Mendhar Nullah
Committed	11	Athmuqam	350 MW	Neelum	Near Athmuqam
	12	Suki Kinari	870 MW	Kunhar	Upstream of Balakot
	13	Mahl	590 MW	Jhelum	Downstream of the confluence with the Mahl Nullah
	14	Azad Pattan	640 MW	Jhelum	About 7 km upstream of Azad Pattan Bridge
Planned	15	Dudhnial	850 MW	Neelum	Near Dudhnial
	16	Balakot	300 MW	Kunhar	Upstream of Patrind
	17	Ashkot	300 MW	Neelum	Near Kundal Shahi
	18	Chakothi-Hattian	500 MW	Jhelum	Just downstream of the Line of Control
	19	Sehra	130 MW	Poonch	Just downstream of the Line of Control
Others	20	Wular	Not an HPP	Jhelum	
	21	Naran	188 MW	Kunhar	
	22	Batakundi	96 MW	Kunhar	
	23	Kotli	100 MW	Poonch	Just upstream of the Gulpur HPP
	24	Rajdhani	132 MW	Poonch	Just downstream of the Gulpur HPP

Brief Description of the Neelum-Jhelum-Poonch Basin-Wide DRIFT DSS

The consolidated DRIFT DSS for the Jhelum-Poonch Basin is an environmental flow assessment DSS set up in October 2016 by combining and extending the DRIFT DSSs used to access the EFlows of individual HPPs in the Jhelum-Poonch Basin since 2010, namely the Kinshanganga HPP (2010), the Neelum-Jhelum HPP (2015b), the Gulpur HPP (2014), the Karot HPP (2016), and the Kohala HPP (2017).

The consolidated DRIFT DSS comprises 25 EFlow sites[1]: 20 on the mainstem rivers (the Neelum, the Jhelum, and the Poonch) and five representing key groups of nullahs as shown in **Table G.A.2**. The table also lists the reach represented by each site and provides the 2012 ecological status of each reach, which is used as the baseline integrity (**Box G.A.1**) throughout the DSS. For sites that were not part of the existing DSSs but for which response curves and other information were extrapolated, the site for when the extrapolation was performed is also provided in **Table G.A.2**.

Table G.A.2: EFlows Sites in the Consolidated Jhelum DSS

	River	EFlow site	Coordinates	Location	Representing	Baseline integrity	Extrapolated from
Mainstem							
1	Neelum	Line of Control	34.6950N; 74.7060E	Upstream of Taobat	Line of Control to Matchal	B	–
2		Dudhnial	34.7050N; 74.1040E	Near Dudhnial	Matchal to Dudhnial	B	–
3		Athmuqam	34.5834N; 73.9088S	Near Athmuqam	Dudhnial to Bata	C	Dudhnial
4		Nauseri	34.3814N; 73,7282E	Upstream of Nauseri	Bata to Nauseri	C	–
5		Panjgiran	34.4408N; 73.6357E	Near Panjgiran	Nauseri to Patikka	C	–
6		Dhanni	34.4408N; 73.6357E	Near Dhanni, immediately upstream of Muzaffarabad	Patikka to Muzaffarabad	C	–
7		Muzaffarabad	34.4020N; 73.4752E	In Muzaffarabad	Muzaffarabad	D	–
8	Kunhar	Khanian	34.7230N; 73.5342E	Between Suki Kinari and Balakot	Upper Kunhar	C	Ambor
9		Paksair	34.4358N; 73.3605E	Between Balakot and Patrind	Lower Kunhar	C	Ambor
10	Jhelum	Upstream Kohala HPP	34.1791N; 73.7155E	Upstream of the Kohala HPP	Line of Control to the Kohala Reservoir	C	–
11		Subrey	34.3552N; 73.5195E	Near Paprusa, upstream of the Neelum-Jhelum confluence	Kohala HPP to the confluence with the Neelum River	C	–
12		Ambor	34.3239N; 73.4671E	Downstream of the Neelum-Jhelum confluence, near Charwa	Confluence with the Neelum River to upstream Neelum-Jhelum HPP tailrace	D	–
13		Kohala	34.1078N; 73.4966E	Near Sangal and Kohala gauging station	Neelum-Jhelum/Kohala HPP tailraces to Karot HPP	D	–
14		Mahl downstream	33.9043N; 73.5839E	Downstream of Mahl HPP	Mahl HPP tailrace to Azad Pattan HPP	D	Kohala
15		Azad Pattan downstream	33.7600N; 73.5753E	Downstream of Azad Pattan HPP	Azad Pattan HPP tailrace to Karot HPP	C	Kohala
16		Hollar	33.5875N; 73.6054E	Near Hollar Bridge	Karot HPP tailrace to Mangla Dam	C	–

[1] EFlows sites are river reaches representative of considerably longer sections of a river. They are the focus sites at which hydrology and hydraulic relationships are computed for use in a EFlow assessment.

River		EFlow site	Coordinates	Location	Representing	Baseline integrity	Extrapolated from
Mainstem							
17	Poonch	Kallar Bridge	33.5785N; 73.9372E	Kallar Bridge	Line of Control to Kotli	C	–
18		Borali Bridge	33.4520N; 73.8580E	Borali Bridge	Gulpur HPP weir to tailrace	C	–
19		Gulpur Bridge	33.4492N; 73.8372E	Gulpur Bridge	Gulpur HPP tailrace to downstream of Gulpur Bridge	C	–
20		Billiporian Bridge	33.3846N; 73.7915E	Billiporian Bridge	Downstream of Gulpur Bridge to Mangla full-supply level	C	–
Tributaries (nullahs)							
21	Neelum	Surgun Nullah	n.a.	Tributaries between the Line of Control and Dudhnial		C	Line of Control
22		Jagran Nullah	n.a.	Tributaries between Athmuqam and Nauseri		C	Mahl Nullah
23		Patikka Nullah	n.a.	Tributaries between Panjgiran and Dhanni		C	Mahl Nullah
24	Jhelum	Mahl Nullah	n.a.	Tributaries between Kohala and Hollar		D	–
25	Jhelum	Kahuta Nullah	n.a.	Tributaries between the Karot HPP and the Mangla Reservoir		C	–

Note: New sites highlighted in green

Box G.A.1: Ecosystem integrity

Ecosystem integrity is an indication of the ecological condition of a part of the ecosystem (such as habitats or fish communities) or of the whole ecosystem relative to its natural condition. Integrity is expressed as an ecological category from A to F as defined below.

Ecological category	Description of the habitat
A	Unmodified: the habitat is still in a natural condition.
B	Slightly modified: a small change in natural habitats and biota has taken place, but the ecosystem functions have essentially remained the same.
C	Moderately modified: loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified: a large loss of natural habitat, biota, and basic ecosystem functions has occurred.
E	Seriously modified: the loss of natural habitat, biota, and basic ecosystem functions is extensive.
F	Critically/extremely modified: the system has been critically modified with an almost complete loss of natural habitat and biota; in the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

Inclusion of Nullahs

The five tributary (nullah) sites shown in **Table G.A.2** were included to represent key groups of nullahs in various reaches of the mainstem, which are important habitats for migratory fish species and sediment supply. The assumption underlying the inclusion of these nullahs is that although they do not have any HPPs located on them, they are subject to other pressures such as overfishing and mining. Thus, in the DSS, the nullah sites have sufficient functionality to estimate the effects of changing protection levels but not enough to evaluate the effect of locating an HPP on a nullah. The way the nullahs have been programmed in the DSS means that protection measures are assumed to be applied to all nullahs in a group (**Figure G.A.2**).

Inundation and Dewatered Zones

The DSS as it is currently programmed does not account for flooded areas associated with the reservoirs. Each HPP included in the scenarios will have an inundated area upstream of its weir.

This inundated zone varies depending on river slope and weir height, but they tend to be between 30 and 70 km for HPPs in the Jhelum Basin. In these areas, riverine habitat is converted to lake habitat and all river features are essentially lost. These areas are neither captured in the DSS nor the maps of the ecosystem integrity linked to the scenarios.

The DSS also excludes dewatered zones of 20 km or less. As such, it includes the dewatered zones resulting from the diversions at the Neelum-Jhelum and Kohala HPPs but excludes those for the likes of the Patrind and Athmuqam HPPs.

DRIFT Jhelum-Poonch Basin DSS: Archiving and Licenses

The DRIFT Jhelum-Poonch Basin DSS Master Database is archived at the offices of Hagler Bailly Pakistan in Islamabad. For information on the database or permission to use the DSS, please contact: Vaqar Zakaria: *VZakaria@haglerbailly.com.pk*.

DRIFT licenses for viewing the DSS and updating response curves are free. DRIFT licenses for full functionality, which includes changing hydrology and scenarios, are subject to an annual license fee of $750. Licenses can be obtained from www.DRIFT-EFlows.co.za or on request from DRIFT@southernwaters.co.za.

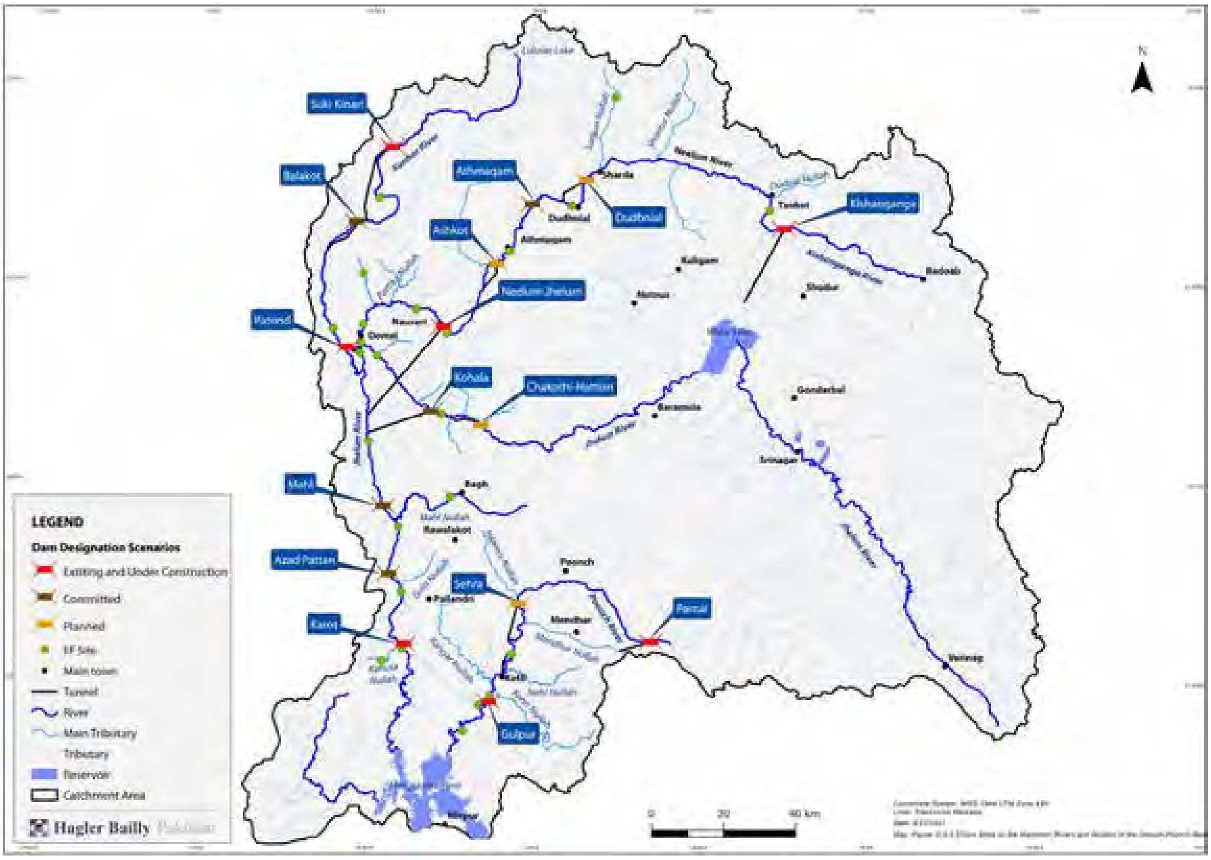
This Report

This report is a summary of the outcome of the tasks assigned to Southern Waters/Koehnken in the *Basin-Wide Studies in the Jhelum-Poonch Basin for Sustainable Hydropower* and does not address the detail behind the setup of the project-specific DSSs. This detail includes:

- The process followed to set up, populate, and run initial scenarios in the basin-wide DRIFT DSS for the Jhelum-Poonch Basin, AJK, is covered in The Consolidated DRIFT DSS for the Jhelum-Poonch Basin, AJK, Progress Report, October 2016
- The details of the DSS, indicators, response curves, operational aspects, and considerations and assumptions underlying the protection levels are covered in various project reports (HBP and Southern Waters 2011 and 2015b) and other literature (Brown et al. 2013)

To this end, **Section G.A.2** is the sediment audit undertaken by Lois Koehnken, **Section G.A.3** covers the various updates to the DSS, **Section G.A.4** provides the agenda and participants for the training and testing workshop, and **Section G.A.5** presents the results of the scenarios assessment with the updated DSS. **Section G.A.6** presents Scenario Results and **Section G.A.7** provides Summary and Conclusion.

Figure G.A.2: EFlow Sites on the Mainstem Rivers and Nullahs of the Jhelum-Poonch Basin, Showing HPPs Modeled in the Neelum-Jhelum Basin-Wide DRIFT DSS



G.A.2
Sediment Audit

This sediment audit focuses on the existing, under-construction, and the committed projects for which information is readily available, as summarized in **Table G.A.3**. Other HPPs in the catchments, such as the Parnai, Uri I, and Uri II, were excluded from this review because there was little or no sediment information available for them.

Table G.A.3: Summary of Existing, Under-Construction, and Committed HPPs Included in the Sediment Audit, by River Subbasin

River	Existing and under-construction HPPs	Committed HPPs
Neelum	Kishanganga (in India-administered Kashmir)	
	Neelum-Jhelum	
Kunhar	Patrind	Balakot
Upper Jhelum	Kohala	
Lower Jhelum	Karot	Mahl
		Azad Pattan
Poonch	Gulpur	

Objectives of the Sediment Audit

The sediment audit is based on the principles of Temane, Le, and Vlek (2014), who showed that expert knowledge and rapid characterization of catchments, in terms of susceptibility to erosion, are viable options for assessing siltation risks and analyzing controlling factors at a larger number of dams.

The sub-tasks addressed in the sediment audit are to collate and evaluate existing data on sediments for the Neelum-Jhelum rivers and use this, in combination with basin geology information, to predict how sediment loads and patterns are expected to change with HPP development in the basin. The initial proposal was to adopt a GIS approach to estimate sediment inputs, but sediment-monitoring results are available for most rivers in the basin; therefore, the sediment values in this assessment are based more on these data as well as sediment-yield data provided in the environmental impact assessment reports for hydropower projects in the region, rather than on estimates using high-level basin characteristics, such as basin geology.

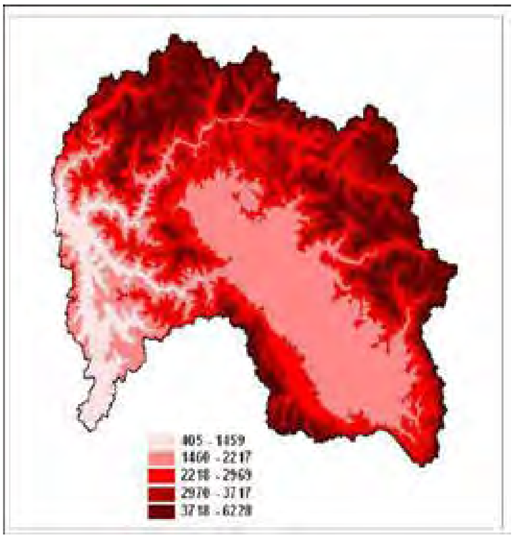
The approach considers sediment as three components: bedload, sand, and silt plus clay to account for their different transport mechanisms and susceptibility to change as a result of hydropower development.

Key questions included: Which reservoirs will trap bedload sediments? When will HPPs attain equilibrium with the catchment-sediment loads? How will sediment patterns change above and below each HPP? And what data and information are required to enhance the understanding of sediment processes in the Jhelum-Poonch Basin?

Catchment Attributes

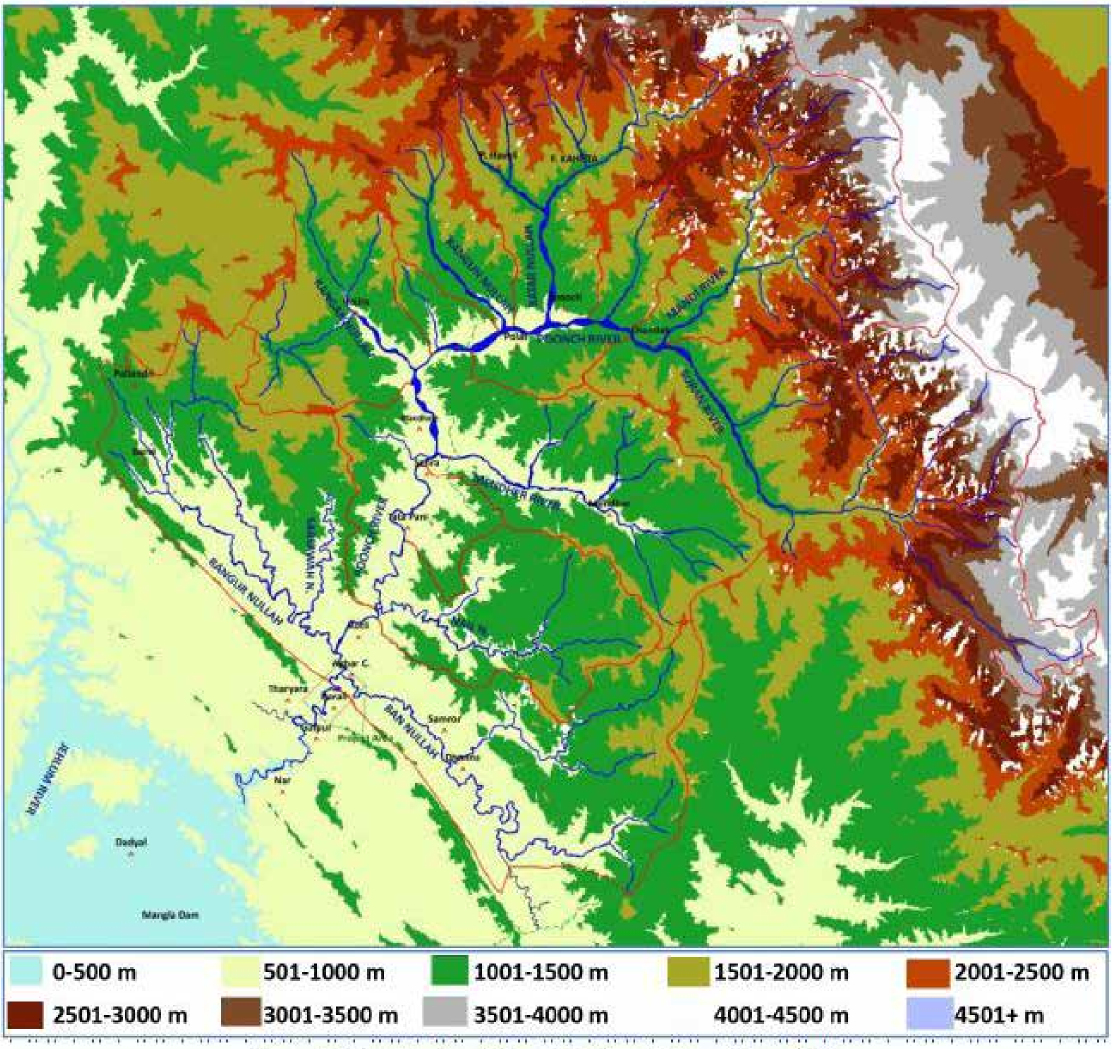
The Neelum-Jhelum and Poonch rivers drain the foothills of the Himalayas and encompass elevations extending from 380 m at the confluence with the Mangla Reservoir to over 5,000 m, snow-capped peaks (**Figure G.A.3** and **Figure G.A.4**). By comparing the dam locations in **Figure G.A.2** with the elevation surfaces in **Figure G.A.3** and **Figure G.A.4**, it is evident that the HPPs are sited in the prominent, lower elevation river valleys. In the Neelum, Kunhar, and middle Jhelum subbasins, these valleys are narrow and surrounded by very steep mountainous areas. Although lower in elevation, the rivers have steep slopes, as shown in **Figure G.A.5** through **Figure G.A.6**. The Neelum River slope increases with distance downstream of the Kishanganga HPP and is steeper than the middle Jhelum River. From the Kishanganga site, the river drops about 1,700 m over around 200 km. The slope of the lower Jhelum River reduces downstream of the confluence. The Kunhar is the steepest of the upper rivers, losing 2,000 m in elevation over around 130 km (**Figure G.A.7**). The long section of the Poonch River only extends to the Line of Control between Pakistan- and Indian-administered Kashmir and shows a concave river profile like the other rivers (**Figure G.A.8**). Elevation bands for the Poonch River, which include the entire basin (**Figure G.A.9**), show a decrease in area with declining elevation, consistent with the broadening of the catchment with distance from the headwaters, with about 60 percent of the catchment above 1,500 m elevation.

Figure G.A.3: Elevation Surface of the Jhelum River Basin



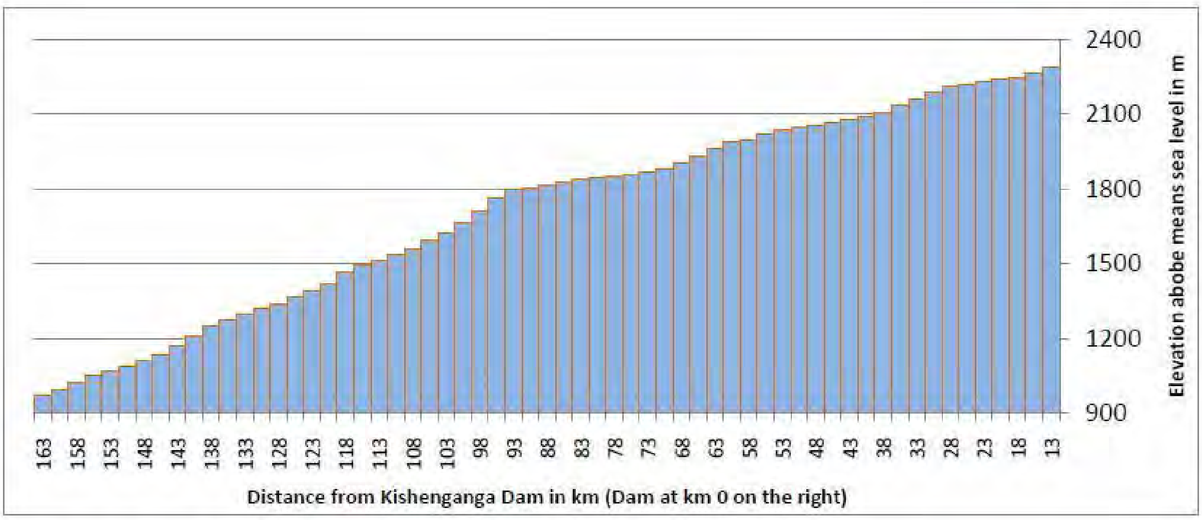
Source: Kohala FS (BIDR 2016)
Note: Units are in meter.

Figure G.A.4: Elevation Surface of the Poonch River Basin



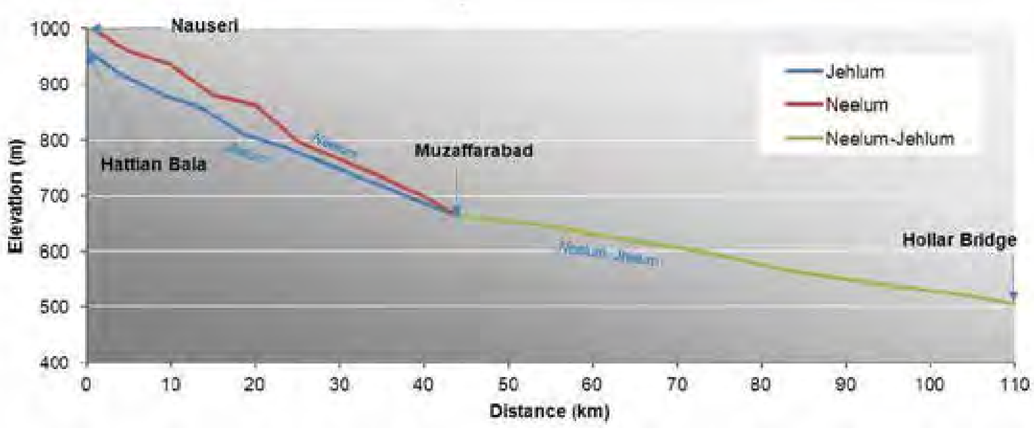
Source: Gulpur ESIA (HBP 2014)

Figure G.A.5: Long Section of the Neelum Valley from the Kishanganga Dam to 163 km Downstream, Near the Site of the Neelum-Jhelum HPP



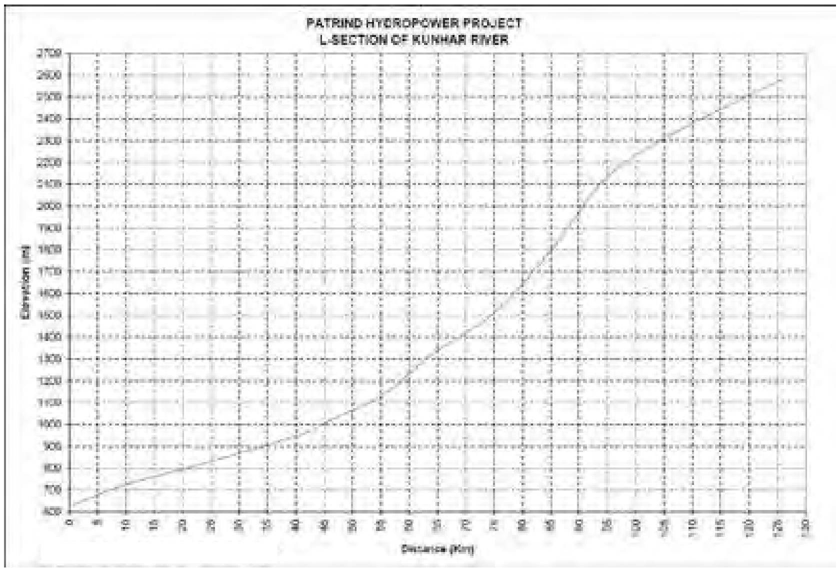
Source: HBP et al. 2011

Figure G.A.6: Long Section of the Neelum and Upper and Lower Jhelum Rivers Showing Elevation and Changes to Slope



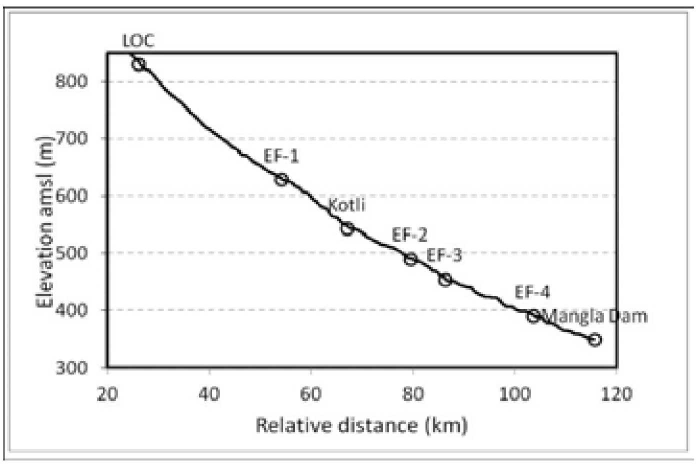
Source: HBP and Southern Waters (2015b)
Note: The Neelum River commences at the site of the Neelum-Jhelum HPP.

Figure G.A.7: Long Section of the Kunhar River



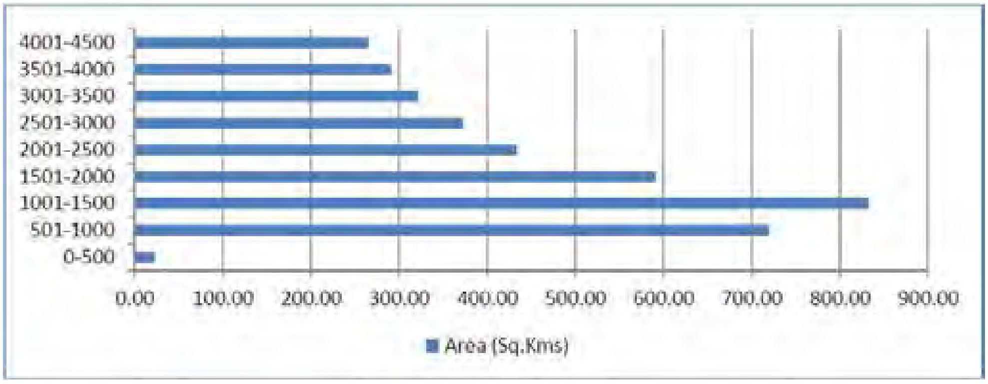
Source: Patrind ESIAs (Pakistan Engineering Services, PVT et al. 2007)

Figure G.A.8: Long Section of the Poonch River



Source: HBP and Southern Waters 2011
Note: EF labels refer to EFlow sites.

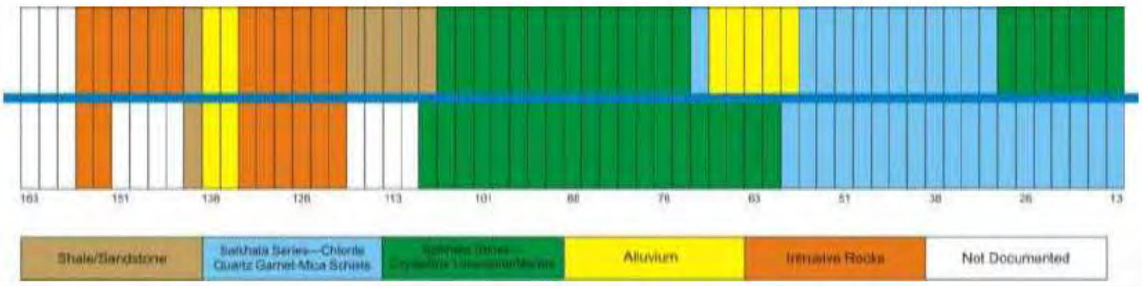
Figure G.A.9: Elevation Bands for the Poonch River



Source: HBP 2014
Note: Total area of catchment = 3,850 km², so each 100 km² is equivalent to 2.5% of the total catchment area

Figure G.A.10: Geology of the Neelum Valley Showing Range of Geologic Units Present and Evidence of Faulting along the River

1. From Taobat (KM 13) to Kel (KM 58), the dominant geological formation (about 79% of the valley) is Salkhala series of chlorite quartz garnet-mica schist, whereas the other main rock type is Salkhala series of crystalline limestone/marble (about 18% of the area)
2. From Kel to KM 108 (near Keran), the dominant formation (about 85%) is Salkhala series of crystalline limestone/marble. About 10% of this zone is covered with alluvium.
3. From KM 108 to Nauseri (KM 163), the valley has mixed geological formation, where the most common formation is the intrusive rock (about 45% of the area)



Source: HBP et al. 2011

Geologically, the area is tectonically active and complex and experiences high rates of seismicity (NORSAR and PMD 2006). **Figure G.A.10** provides an example of the geologic units present in the Neelum River, showing that numerous units are present over relatively short distances reflecting the intense folding and faulting of the area. The presence of different lithologies on opposite banks of the river suggests it may be occupying a fault zone. Quartz is abundant in several of the geologic units common throughout the Jhelum-Poonch Basin and this resistant mineral is present in high quantities in the sand load of the river, making management of sand a prominent issue for turbine maintenance and reservoir capacity. Other minerals, such as micas or carbonates, are relatively soft and quickly abrade to silt or clay-sized material, contributing to the large silt load of the rivers, or dissolve completely.

Geomorphic Processes Affecting Sediment Transport

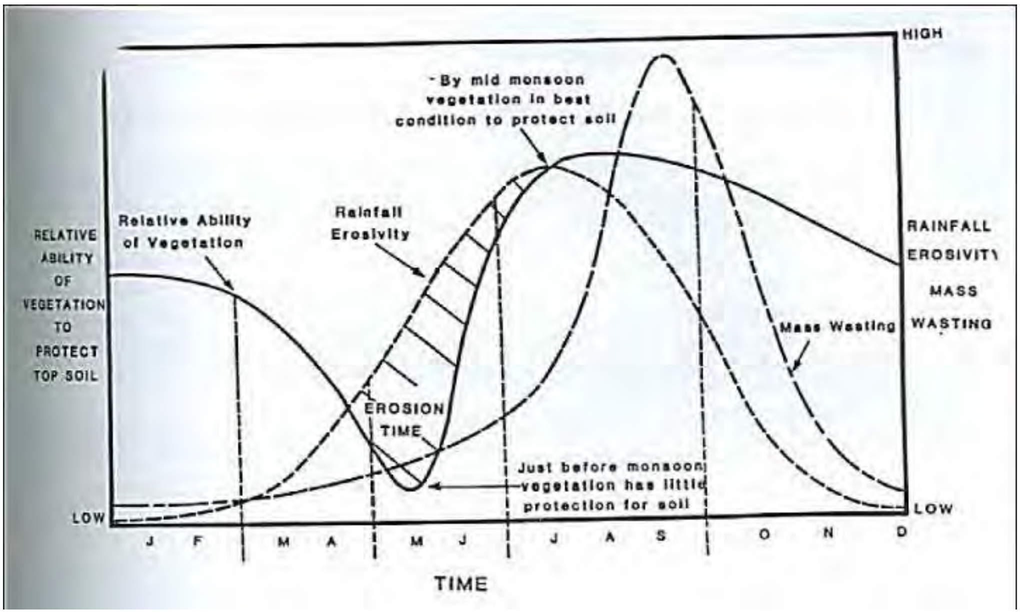
Many factors affect sediment transport and geomorphology in a river catchment. At the largest scale, the region is experiencing rapid tectonic uplift, which is a major determinant in erosion, as mountains typically erode at a rate similar to uplift (Milliman and Syvitski 1992). The strong tectonic forces can shear and weaken rock units, making them more susceptible to weathering and physical erosion (Hren et al. 2007). Tributaries are the main source of sediments to the mainstem rivers with sheetwash and gully erosion associated with high rainfall, and mass-wasting events such as landslips and avalanches identified as important processes (Norconsult and Norplan 1997). As shown in **Figure G.A.3** and **Figure G.A.4**, the tributaries and valley walls of the main rivers are exceedingly steep, and can rapidly deliver the large volumes of sediment generated by these processes to the main valleys. The sediment grain sizes generated by these processes range in size from boulders of more than 1 m to clay (Norconsult and Norplan 1997). Additional activities that can contribute to sediment loads in rivers include road construction, livestock grazing, agriculture, and deforestation. Due to the steep nature of the main rivers in the Jhelum-Poonch Basins and the high rainfall, the rivers have sufficient energy to transport the material being "shed" by the rapidly uplifting mountainous terrain resulting in deeply incised and steep valleys with limited accumulation of alluvial deposits in most areas (Norconsult and Norplan 1997).

The relative importance of different erosional processes compared to the stability provided by vegetation and rainfall patterns over a year in the Himalaya is shown in **Figure G.A.11**. The onset of the wet season is a time of high-erosion risk owing to low stability provided by vegetation after the extended dry winter. During this period, large volumes of sediments are delivered to the rivers ("erosion time" in **Figure G.A.11**). As the monsoon progresses, vegetation recovers and increases slope stability, thus reducing the erosive impact of rainfall. At the end of the monsoon, as hillslopes become saturated, the risk of mass wasting (such as landslips, avalanches, and riverbank collapse) increases, providing episodic sediment input to rivers. In addition to the processes depicted in **Figure G.A.11**, snowmelt and glacial erosion are also important sediment-input processes in the Neelum-Jhelum rivers.

The complexity of erosion and stability processes in the steep and tectonically active landscape results in river systems where sediment transport is determined more by sediment delivery to the rivers rather than by the transport capacity of the rivers (for example, discharge). This facet of the landscape results in the following characteristics:

- Sediment transport is highly variable over both short- and long-time frames.
- The high variability of sediment delivery to the rivers makes quantifying sediment transport difficult, as even daily measurements are unlikely to capture all variability. Norconsult and Norplan (1997) highlighted the difficulty of accurate sediment collection owing to the high river velocity

Figure G.A.11: Interaction Stability Provided by Vegetation and Erosional Processes over a Year



Source: Norconsult and Norplan 1997

and light weight of the sampler preventing it from being deployed over the entire water column, thus not sampling material transported near the riverbed. Inappropriately sized sediment-monitoring equipment that filled too quickly with surface water was also flagged as an issue resulting in underestimated sediment-transport rates (Norconsult and Norplan 1997).

- The high turbulence and velocity of the rivers, combined with shifting channels, makes the collection of accurate flow measurements difficult. All errors in flow measurement will be reflected in sediment-load calculations. These potential errors, combined with the inherent variability of the rivers, need to be recognized when interpreting sediment budgets or identifying potential mitigation and management measures.
- There is a poor correlation between river flow and sediment transport because the latter is governed more by sediment delivery to the rivers than by the transport capacity of the rivers. For example, the rivers typically have sufficient energy to transport all sediment delivered to the valley floor, so the limiting factor is sediment supply rather than river flow.
- Sediment delivery and transport is affected by episodic events with the capacity to block the river, such as glacier-lake-outburst floods, landslips, and avalanches (**Figure G.A.12**), or other large mass-wasting events that can deliver far greater than the "average" sediment load to the river in a short time.

Introducing hydropower to such an active and dynamic landscape will affect sediment transport in the following ways:

- Hydropower impoundments trap sediments and alter the quantity and characteristics of sediments in the downstream river. The grain sizes affected and the degree of trapping are related to the morphology and size of the impoundments, but all gravels and most sand-sized material is generally trapped while large proportions of fine silt and clay-sized material can be transported through storages. The periodic flushing of sediment from impoundments can create sediment pulses with concentrations that far exceed "natural" concentrations and may alter the timing of sediment delivery relative to seasonal cycles.
- Hydropower discharges usually have reduced variability relative to the natural-flow regime because of the "quantum" of flow required for each turbine. This increases the duration of flow within narrow-flow bands, removes riparian vegetation through inundation and waterlogging, and can exacerbate erosion at specific levels in the rivers as a result of the concentration of river energy undercutting banks.
- Hydropower-peaking operations add pressure on downstream banks because the rapidly changing water levels increase the rivers' erosive power. The constant wetting and drying of banks increases their susceptibility to erosion and stresses vegetation.
- Hydropower operations that divert water between catchments affect both the donor and recipient catchment by changing the flows and river energy available for transporting sediment as well as diverting fine sediment and water.

Figure G.A.12: Google Earth Image of a Landslip Altering the Flow of the Lower Jhelum River about 35 km Downstream of Muzaffarabad

Sediment Transport Characteristics

Sediment Loads

The suspended sediment data used in the feasibility studies listed in **Table G.A.3** are summarized in **Table G.A.4**. The "periodicity of data" indicates the time-step at which the results are presented and not the monitoring frequency, for example, the daily data is not available every day for the period of record, but rather some daily measurements are available for the period. The station with the longest record is Kotli in the Poonch River. In the Jhelum, the Patrind HPP site has the longest record, but no results are available for the past 15 years, so recent changes involving land use or hydropower development are not captured in the available monitoring results. Sediment-transport monitoring in the Jhelum and Poonch basins has been limited to the collection of suspended sediment, with no bedload measurements collected at any site.

A summary of catchment, flow, and sediment-transport information derived from the feasibility studies for each existing or potential HPP site included in the analysis is provided in **Table G.A.5**. Where possible, ranges of suspended sediment transport loads are included. Bedload transport was estimated in the various ESIAs by assuming a fixed percentage of the suspended sediment load. These estimates ranged from 10 percent to 30 percent (**Table G.A.5**).

The results of the ESIAs were used to derive sediment yields (metric tons /km²/yr) for the sites. These yields are average values, and sediment input can vary markedly over short distances. An example is provided in the upper Kunhar River where sediment yields varied more than 10-fold between Naran, a site located near the headwaters, and sites monitored further down the catchment (**Figure G.A.13**). Based on the derived sediment yields, the middle Jhelum River has a very low yield largely attributable to the trapping of sediment in Wular Lake and the Uri power developments located in the basin upstream of the Line of Control. The sediment volumes estimated for the Kohala damsite reflect sediment input from downstream of the lake, which is a considerably smaller catchment area. The Kunhar River at the Balakot and Patrind HPPs has similar sediment yields, while the Neelum River at the Neelum-Jhelum HPP head pond shows the highest yields. The sediment yields in the Lower Jhelum are intermediate between these values.

Table G.A.4: Summary of Sediment Transport Data Available in Feasibility Studies

Stations with sediment data available from current feasibility studies	Periodicity of data	Period of data
Kohala damsite–Upper Jhelum	Yearly	1965–2004
Azad Pattan–Lower Jhelum	Monthly	1979–2004
Gari Habibullah–Kunhar River	Daily	1975–1994
Talhatta–Kunhar	Daily	1995–1996
Paras Bridge–Kunhar	Daily	2012–2013
Kotli–Poonch	Daily	1965–2011
Patrind–Kunhar	Daily	1960–2002

Table G.A.5: Summary of HPP Catchment Areas, Flow Rates, and Sediment-Transport Rates

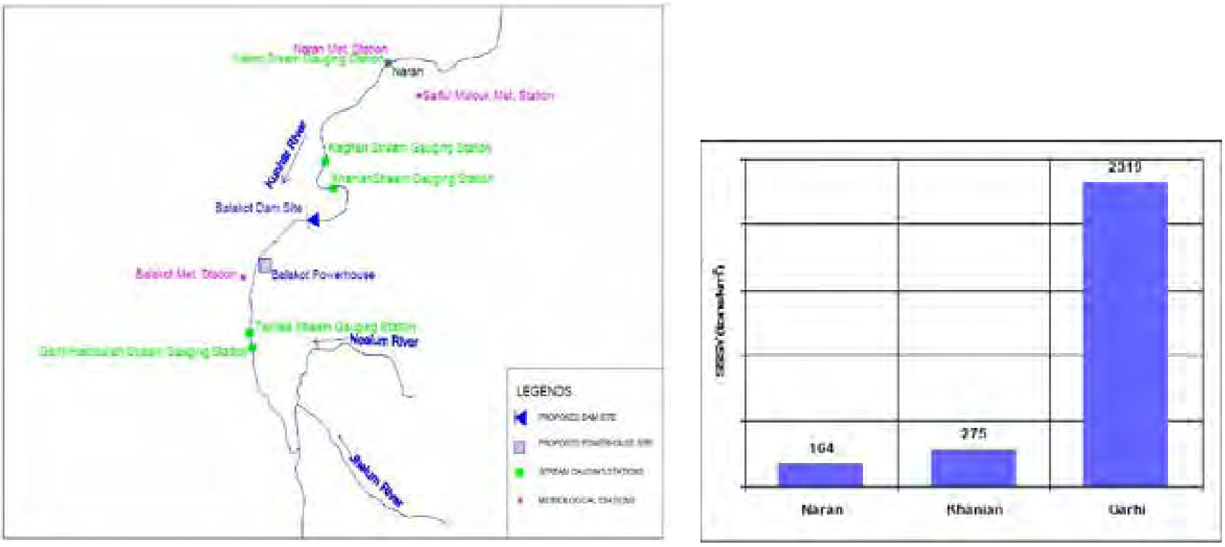
River/ Site	Catchment Area Km²	Average Annual Discharge and Volume (Mm³) (HBP2018a)	Annual Suspended Sediment Mt/yr.	Annual Bedload Sediment Mt/yr. (% Suspended Sediment Load)	Sediment yield (tons/km²) (estimated)
Neelum/ Kishanganga HPP	1,815	104 m³/s 3,280 Mm³	1.23 Mt/yr[2]		375 t/km²
Neelum/ Neelum-Jhelum HPP	7,278	365 m³/s 9,000 Mm³ (Nauseri)	11.5 Mt/yr (up to 19.7 observed)	3.4 Mt/yr (30%)	2,245 t/km²
Upper Jhelum/ Kohala HPP	14,060	302 m³/s 9,520 Mm³	3.17 Mt/yr (0.7 – 9.2)	0.47 Mt/yr (15%)	225 t/km² (based on total upstream catchment area)
Muzaffarabad/ Neelum R	7,278	336 m³/s 10,600 Mm³	16.3 Mt/yr Based on yield		2,245 t/km²
Kunhar/ Balakot HPP	1,951	91.8 m³/s 2,895 Mm³	2.36 Mt/yr (0.33 – 11.7 Mt/yr)	0.35 Mt/yr (15%)	1,855 t/km²

[2] Derived from sediment modeling

River/ Site	Catchment Area Km²	Average Annual Discharge and Volume (Mm³) (HBP2018a)	Annual Suspended Sediment Mt/yr.	Annual Bedload Sediment Mt/yr. (% Suspended Sediment Load)	Sediment yield (tons/km²) (estimated)
Kunhar/ Patrind HPP	2,429		4.72 Mt/yr		1,900 t/km²
Domel/ Jhelum	14,505	321 m³/s 10,123 Mm³	3.44 Mt/yr		
Lower Jhelum at Kohala discharge		780 m³/s 24,598 Mm³	(19.78) Mt/yr (HBP2018a)[3]		
Lower Jhelum / Mahl HPP	25,334	796 m³/s 25,102 Mm³	30.3 Mt/yr (3.6 – 77.8)	4.54 Mt/yr (15%)	1,195 t/km²
Lower Jhelum/ Azad Pattan HPP	26,500	811 m³/s 25,576 Mm³	35.87 Mt/yr (10-86.7 Mt/yr)	5.4 Mt/yr (15%)	1,386 t/km²
Lower Jhelum / Karot HPP	26,700	819 m³/s	33.15 Mt/yr	4.97 Mt/yr (15%)	1,242 t/km²
Poonch R	~3,800 to project site	126 m³/s	10.8 Mt/yr (HBP 2014)	1.1 Mt/yr (10%)	3,315 t/km²
Mangla Reservoir	33,340	905 m³/s (from Jhelum only)	52 Mt/yr (reported as 58M short-tons)		1,600 t/km²

Note: Muzaffarabad and Domel are included to provide information about total inputs from Neelum and Jhelum Rivers, respectively.

Figure G.A.13: Comparison of Sediment Yields from the Kunhar River Basin and Location Map



Source: Balakot Feasibility Study (Mirza 2013)
Note: Garhi is the most downstream stream-gauging station and Naran is the most upstream. Sediment yield associated with the Patrind HPP site is lower than that at Garhi, highlighting variability.

The reported results were used to construct a sediment budget for the Mangla Reservoir (**Table G.A.6**), showing the sediment derived from each sub-catchment upstream of the confluence at Muzaffarabad, the Lower Jhelum, and the Poonch River. Both suspended and bedload sediments are included. The balance suggests that the Neelum River is the largest source of sediment in the Neelum-Jhelum-Poonch Basin, contributing almost half of the sediments to the lower Jhelum River and more than a third of the sediment reporting to the Mangla Reservoir. The middle Jhelum and Kunhar rivers contribute 10 percent and 14 percent of the load in the lower Jhelum River, respectively, resulting in about 70 percent of the Jhelum sediment load being derived from the middle Jhelum, Neelum, and Kunhar rivers. Inputs in the lower Jhelum appear to be evenly distributed between the area draining to the Mahl

[3] Measurements considered unreliable

and Azad Pattan HPP sites. No change in sediment load is recorded between the Azad Pattan and Karot sites. The Poonch River is estimated to contribute about 12 Mt/yr, or 24 percent of the load entering the Mangla Reservoir.

The total calculated sediment load entering the Mangla Reservoir is 50.1 Mt/yr, similar to the calculated average rate of annual deposition within the reservoir of 52 Mt/yr based on hydrographic surveys conducted at three-to-five-year intervals of the impoundment (Pakistan Engineering Services, Fichtner, and K.G. Stuttgart 2007). The Mangla Reservoir is a large and broad waterbody and sediment trapping is between 90 percent (Pakistan Engineering Services, Fichtner, and K.G. Stuttgart 2007) and close to 100 percent (Norconsult and Norplan 1997). The range of sediment deposition in the impoundment (25–94 Mt/yr) shows variability, consistent with the variable nature of sediment delivery from the catchments.

The sediment budget is presented graphically in **Figure G.A.14**. The average values result in a very good sediment balance and provide a framework for quantifying future changes. However, "average" years rarely occur, and understanding the variability of sediment transport and the characteristics of sediments are necessary to predict how sediment loads will change under hydropower scenarios.

Sediment Transport Variability

The variability of sediment transport annually is demonstrated by the results available for the Patrind HPP site (the Kunhar River), the Mahl HPP site (the lower Jhelum River) and the Poonch River (**Figure G.A.15**). All the sites show exceedingly high variability, with few years having average results. At Patrind, maximum annual loads are around fourfold higher than the average value; at Mahl, the highest value is slightly more than twice the average value, with the reduction in variability reflecting the integrating effect of a location lower in the catchment. In the Poonch River, the variability is highest, with maximum loads exceeding the annual average by greater than sevenfold.

Similar variability is observed at the monthly and daily scales. The average monthly values for the same sites as shown in the previous figure are shown in **Figure G.A.16**. The data from the two sites in the Jhelum River show well-defined seasonal patterns, with maximum transport occurring in May to July. The Poonch River data indicate maximum sediment transport in July and August with a smaller peak in March.

Daily sediment loads recorded for the Kunhar and Poonch sites (**Figure G.A.17**) show that within any month, daily sediment-transport rates vary greatly, typically over at least two orders of magnitude. The wide range of results in March in the Poonch River also suggest that the higher average monthly values are related to rare events rather than "typical" conditions, as 75th percentile value (top of box) is lower than the equivalent value in February or April.

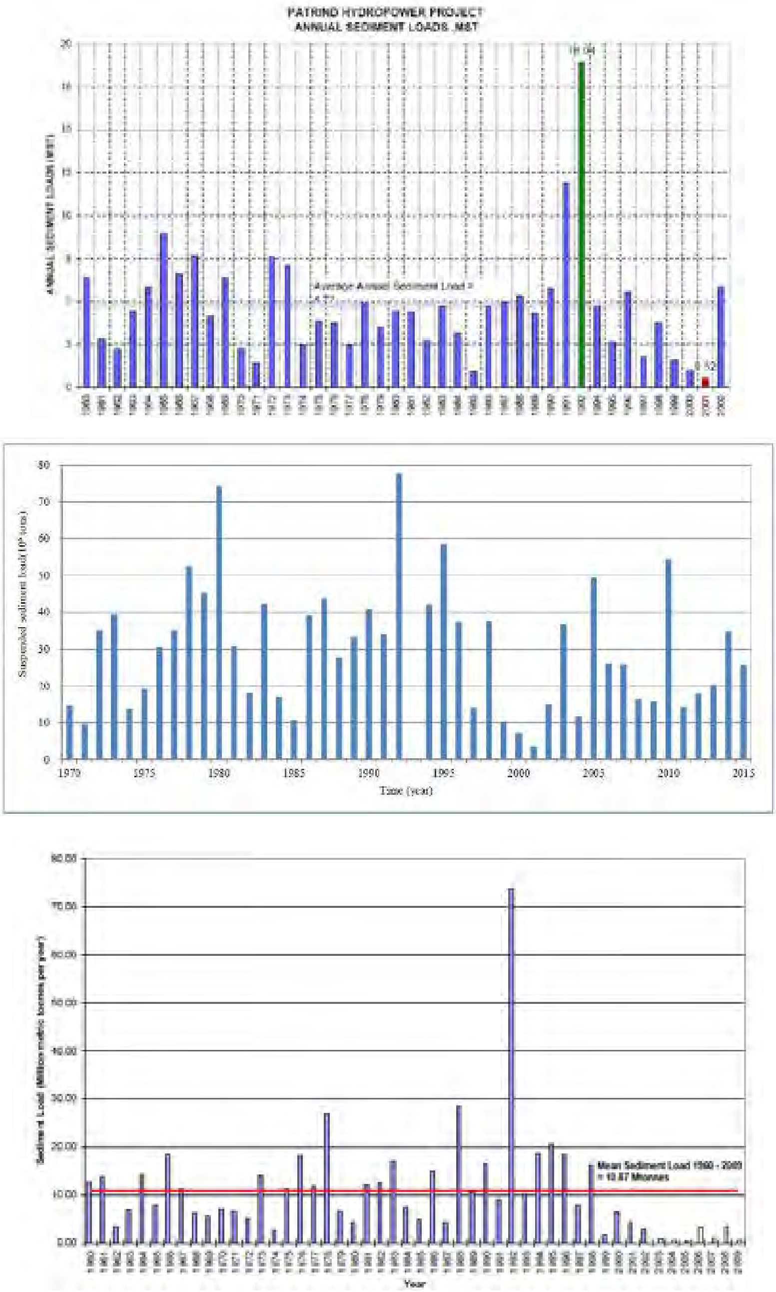
This high variability is important when evaluating potential changes to the river system because of hydropower development and identifying appropriate mitigation measures.

Table G.A.6: Sediment Budget in the Jhelum-Poonch River Basins Based on Average Annual Sediment Loads Reported in ESIAs Compared to Long-Term Infilling Rates of the Mangla Reservoir

River	Suspended sediment input (Mt/yr)	Bedload input (Mt/yr)	Total input (Mt/yr)	Percent of Jhelum (based on 40 Mt/yr)	Percent of total entering Mangla
Upper Jhelum at Domel	3.4	0.51	3.92	9.8	7.8
Neelum at Muzaffarabad	16.3	2.45	18.75	46.9	37.4
Kunhar at Patrind	4.7	0.71	5.53	13.8	11.0
Total to Lower Jhelum	24.4	3.67	28.2	70.5	56.3
Lower Jhelum at Mahl	30.3	4.5	34.8	87.3	69.5
Lower Jhelum at Azad Pattan	35.9	5.4	41.3	100	72.4
Lower Jhelum at Karot-entering Mangla from Jhelum	33.2	5.0	38.2	100	76.1
Entering Mangla from Poonch	10.8	1.1	11.9		23.8
Total entering Mangla	44.0	6.1	50.1		100
Total estimated entering Mangla based on infilling			52.0		

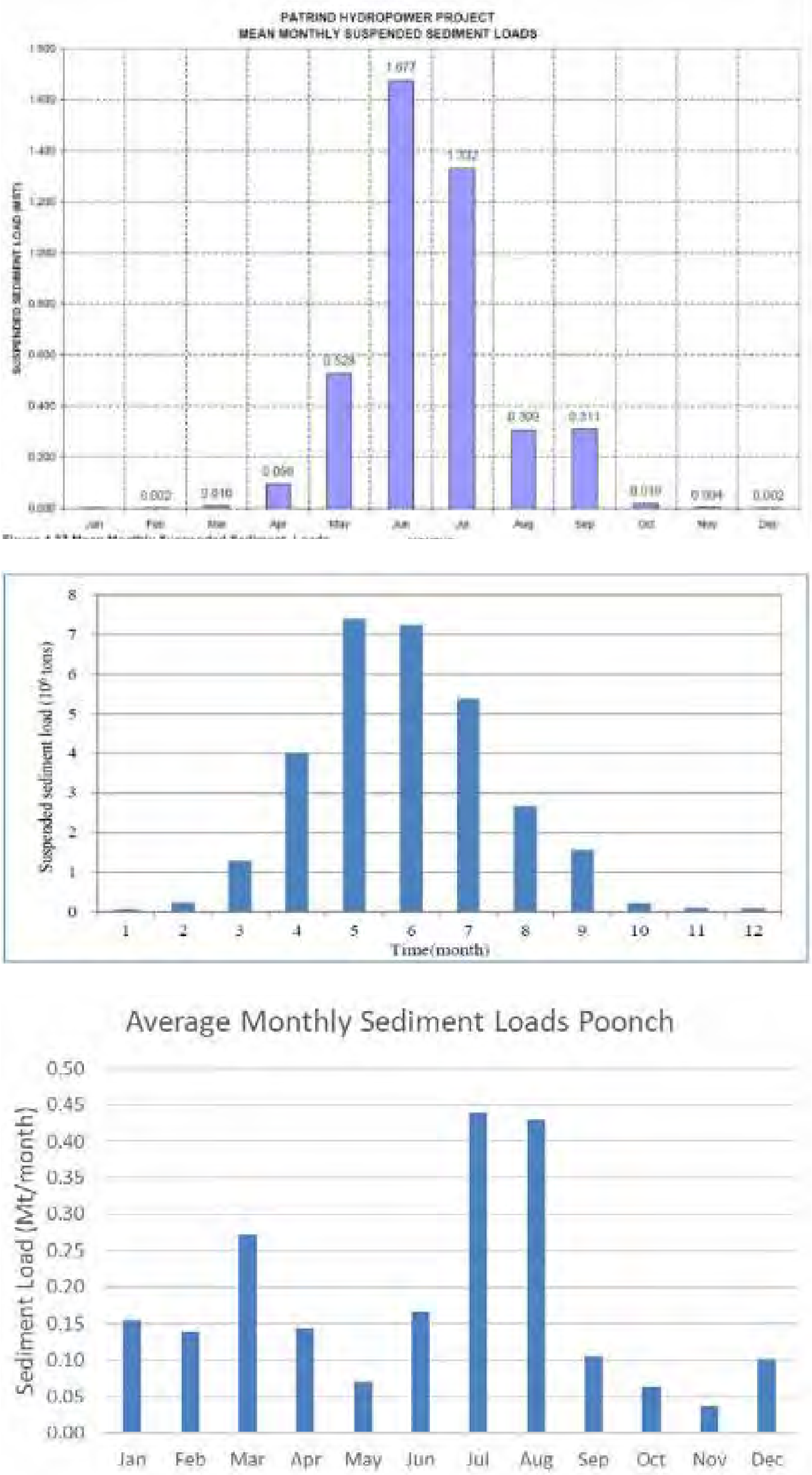
Figure G.A.14: Sediment Inputs by Tributary or HPP Location Based on Sediment Budget

Figure G.A.15: Annual Suspended Sediment Loads at the Patrind HPP Site, the Mahl HPP Site, and the Poonch River



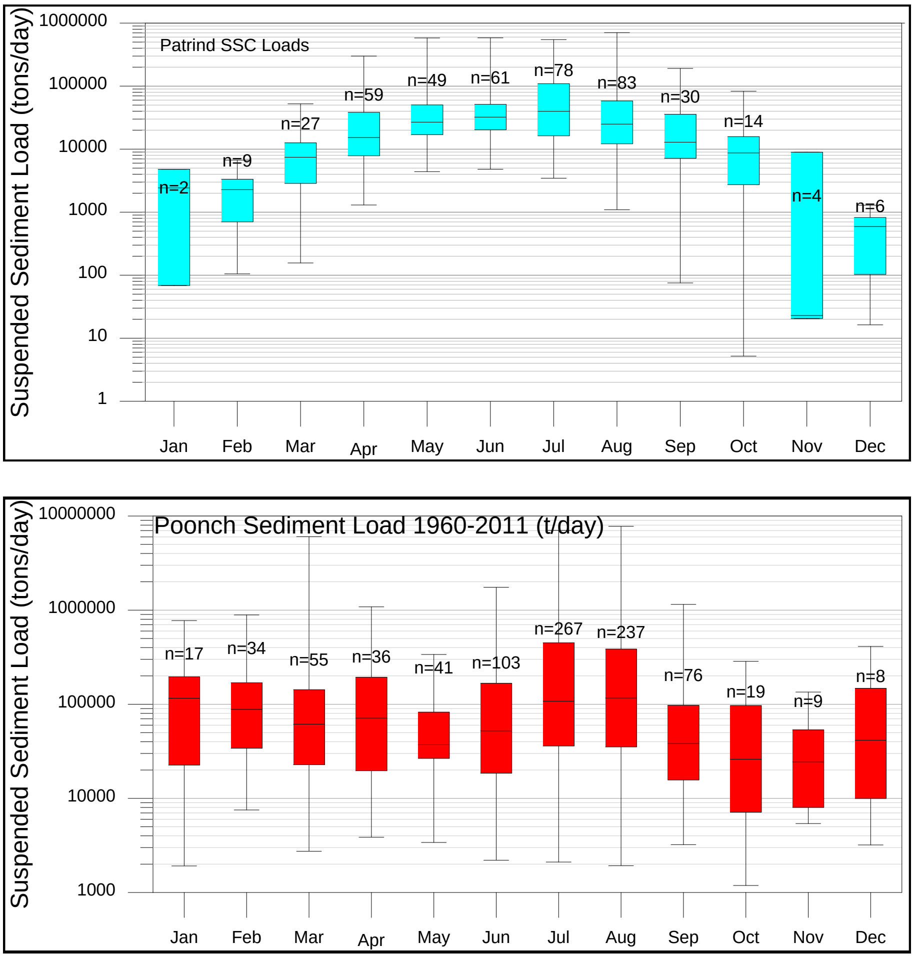
Source: Pakistan Engineering Services, Fichtner, and K.G. Stuttgart 2007; Mahl Feasibility Report (SIDRI 2017); Mott MacDonald 2011
Note: Average values indicated by lines in graphs

Figure G.A.16: Average Monthly Sediment Loads for the Patrind HPP Site, the Mahl HPP Site, and the Poonch River



Source: Pakistan Engineering Services, Fichtner, and K.G. Stuttgart 2007; Mahl Feasibility Report (SIDRI 2017); Mott MacDonald 2011; sediment-load figures for the Poonch River were derived by aggregating the available daily data

Figure G.A.17: Daily Suspended Sediment Results Grouped by Months, Showing Variability of Measurements within Each Month



Note: The "box" encompasses the 25th to 75th percentile results, with the median denoted by a line. The "whiskers" indicate the minimum and maximum values.

Sediment Grain-Size Distribution

The grain size of sediment largely determines how it will be affected by hydropower developments, and how it will affect hydropower infrastructure. This analysis of grain size aims to provide guidance on how the sediment loads at each HPP included in this investigation are likely to change. In HPPs with small impoundments, most silt and clay can be maintained in suspension and passed through the impoundment via the powerhouse or direct release of water. Fine sand (and coarse silt) can be maintained in suspension if water velocities are sufficient but are likely to accumulate within impoundments during low flows. These size fractions can frequently be remobilized during higher flow and be moved through the system. Gravels and larger-sized material are effectively trapped because of the high velocity required for transport and the substantial reduction in velocity that corresponds with the upstream environment of most HPP impoundments. Medium and coarse sand tends to be trapped in impoundments, along with gravels, however, sand is more readily resuspended by sluicing or flushing compared to gravels, for which transport is typically limited to bedload. Gravels initially accumulate at the upstream end of the impoundment, creating a delta that infills the valley. This delta "grows" (progrades) downstream toward the dam wall as bedload is transported over the surface of the delta and deposited at the delta front. The rate of movement of the delta toward the dam can be increased by flushing, which will move bedload downstream. Once the delta front reaches the toe of the dam, material can be "flushed" through low-level gates as bedload. The time required for this to occur will depend on the rate of bedload input to the impoundment, the length and morphology of the impoundment, and the frequency of flushing.

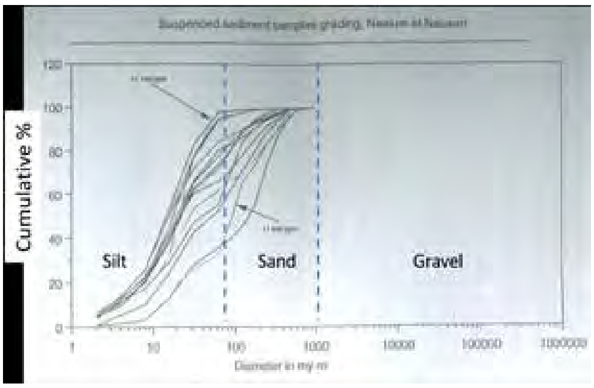
The grain size distribution of suspended and bedload samples collected as part of the ESIA investigations for several HPPs are shown in **Figure G.A.18**. The results are presented at varying scales and axes, but the delineation between sand and silt is indicated on each figure (around 0.06 mm or 6μm). The samples show large variability, but there are some common characteristics:

- Suspended sediment contains abundant silt and clay (less than 63µm).
- The median grain size of suspended material varies considerably between sites. For example, at Neelum-Jhelum, median values (50 percent) range from 15 µm (fine silt) to 200 µm (fine sand), whereas at the Balakot HPP in the Kunhar River, median grain size is around 300 µm (medium sand).
- Sand generally contributes less than 50 percent of the sediment load.
- Bedload material can range from the size of sand to boulders larger than 1 m.

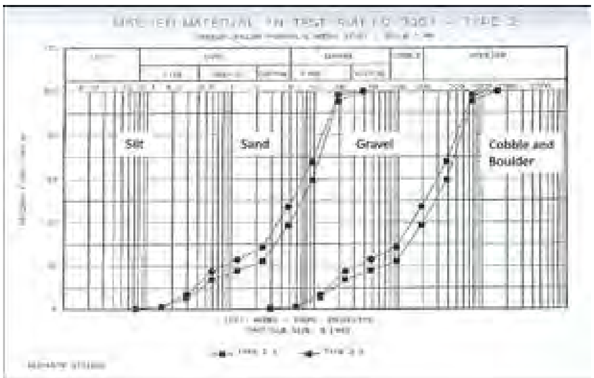
The bedload results from Patrind show low levels of gravel, with sand and cobbles being the dominant fractions. This distribution is consistent with the armoring of the bed, which occurs when rivers have sufficient energy to transport sand and gravels but not cobbles or boulders, resulting in a layer of exposed cobbles and boulders on the riverbed. These large-sized rocks typically overlie finer material (sands and gravels) that are protected from the river flow. In the dry season, finer sediment may also be temporarily deposited on the riverbed, enhancing the bimodal grain-size distribution of bed material. Armoring was highlighted as a potential issue in the head pond of Neelum-Jhelum (Norconsult and Norplan 1997); the concern was that the flushing flow would be insufficient to transport cobbles and boulders, therefore trapping sediment material within or upstream of the armored areas.

Grain-size distribution varies with season, as shown by applying the Mahl grain-size distributions to the sediment loads collected during the same months (**Figure G.A.19**). As the proportion of sand is higher during the months when sediment transport is higher, the total sand load will be greater than if the "average" sand content is applied to the "average" sediment load. The sediment load and grain-size distribution at the Patrind HPP site in the Kunhar River shows less seasonality when compared to Mahl, with sand present throughout the year, contributing between 3 percent and 43 percent of the suspended sediment load (**Figure G.A.20**). Comparing these results highlights the variability of sediment input to the different rivers and highlights the difficulty of predicting the trapping rates or flushing efficiency of hydropower projects, which are dependent on site-specific information.

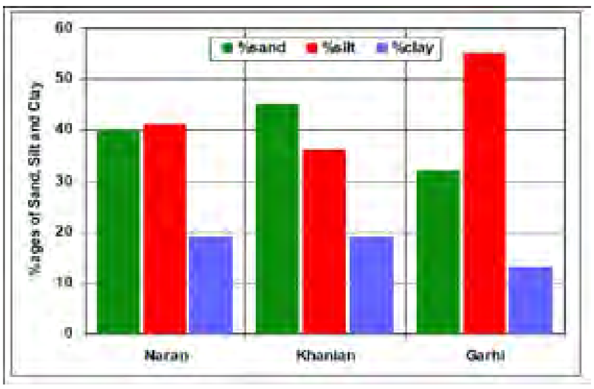
Figure G.A.18: Grain-Size Distribution of Suspended and Bedload Sediment from the Neelum, Kunhar, and Jhelum Rivers



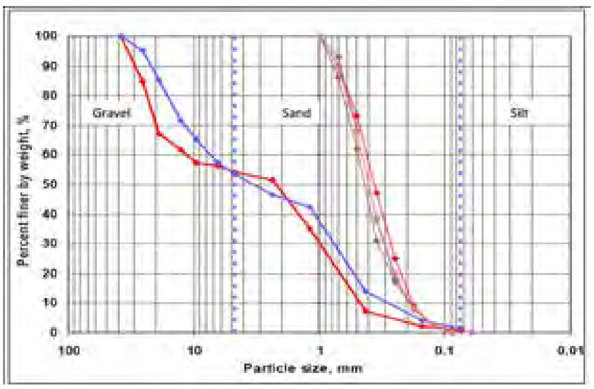
Neelum-Jhelum: Suspended sediment at the Nauseri damsite in the Neelum River showing a wide range of grain-size compositions (Norconsult and Norplan 1997)



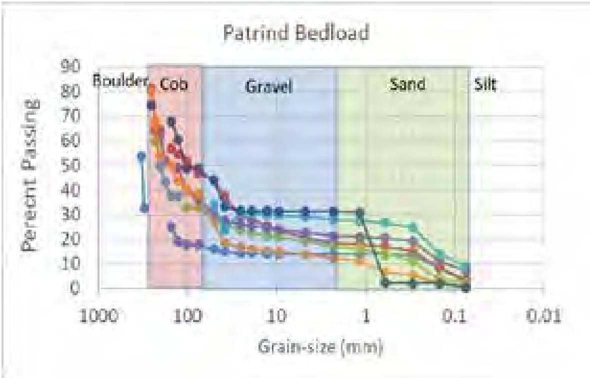
Neelum-Jhelum: Material deposited in the head pond under different flow tests (Norconsult and Norplan 1997)



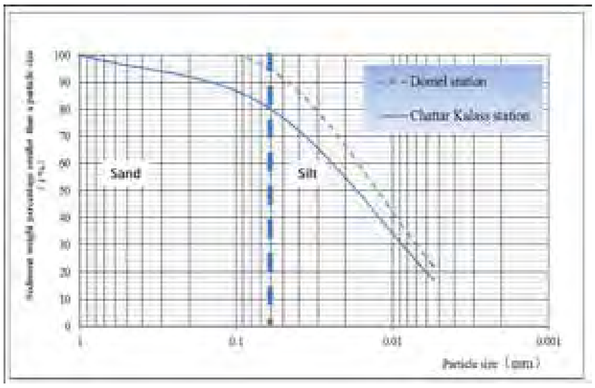
Grain-size distribution of suspended sediment at the Kunhar gauging sites, with locations shown in **Figure G.A.13** (Mirza 2013)



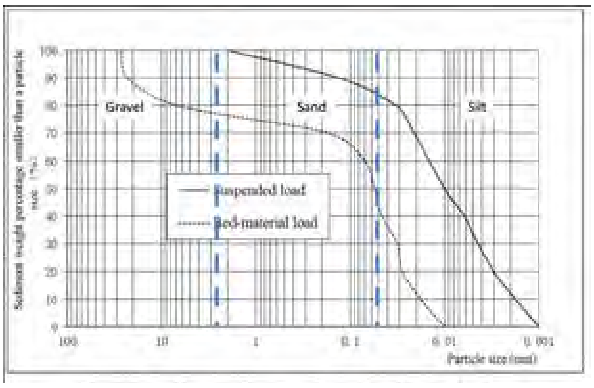
Grain-size distribution curves at the Balakot damsite in the Kunhar River; the left two lines show results for bedload, while the other three lines are suspended sediment (Mirza 2013)



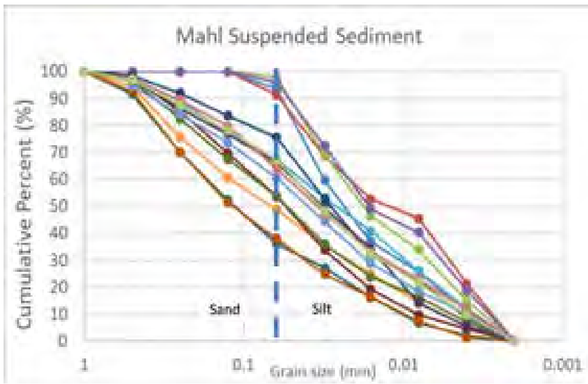
Grain-size distribution of bedload in the Kunhar River at the Patrind HPP site; each line shows the results of one sample (Pakistan Engineering Services, Fichtner, and K.G. Stuttgart 2007)



Grain-size distribution results from gauging sites in the Middle Jhelum (BIDR 2016)



Bed load and suspended sediment grain-size distribution results from the Kohala damsite (BIDR 2016)



Lower Jhelum at the Mahl damsite—Mahl ESIA (HBP 2018a)

Figure G.A.19: Grain-Size Distribution at Mahl Applied to the Monthly Sediment Load

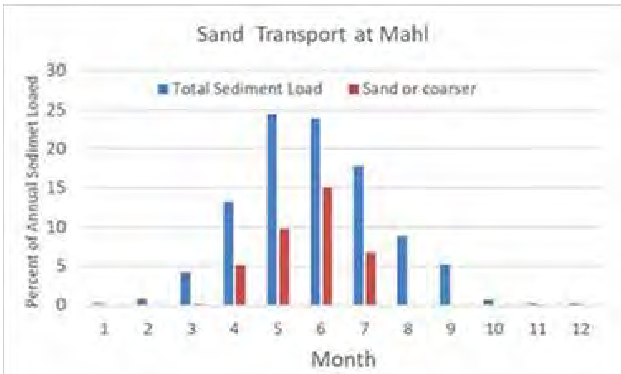
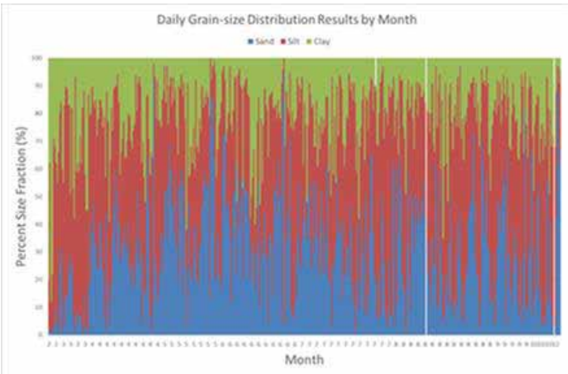


Figure G.A.20: Grain-Size Distribution by Month at the Patrind HPP Site in the Kunhar River



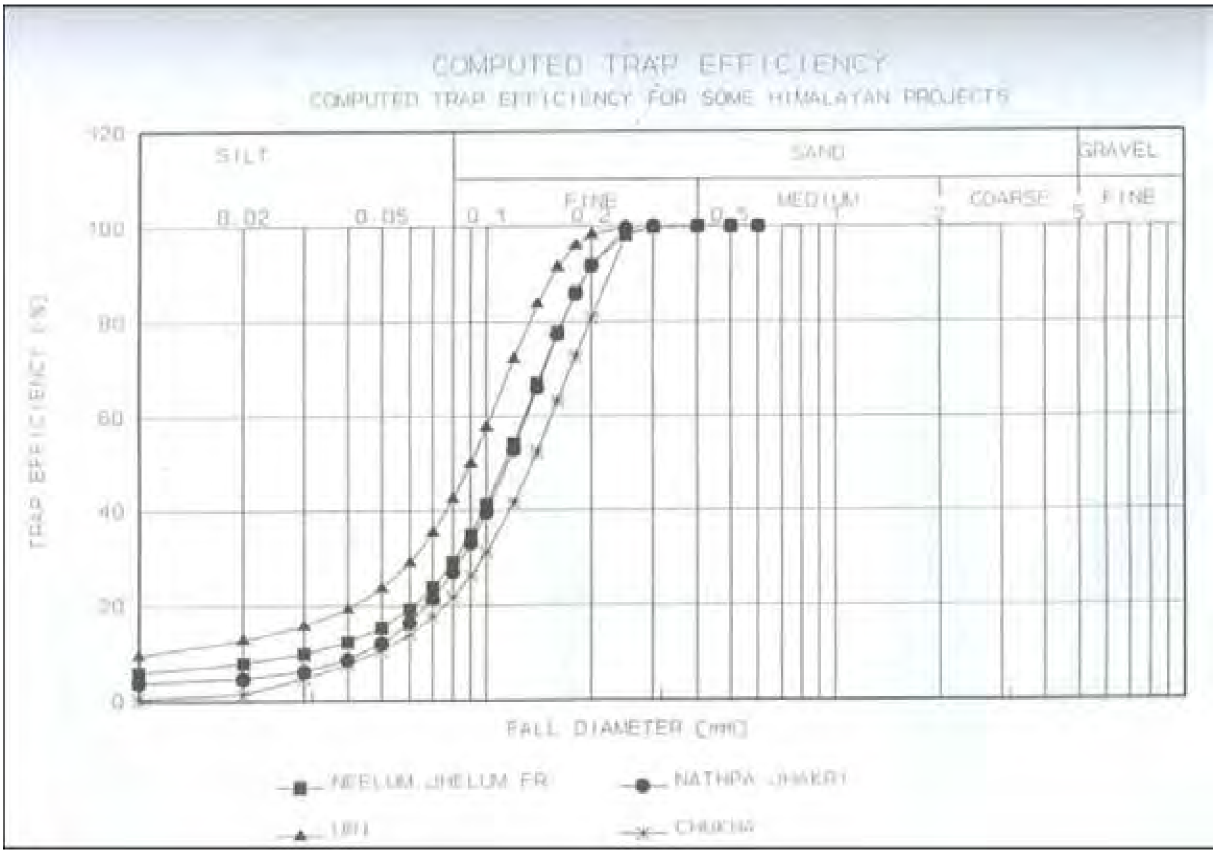
HPP Impacts on Sediment Transport

Each HPP in the Jhelum and Poonch catchments will affect the movement of sediment locally and further downstream. In the Jhelum, where there are numerous intrabasin transfers, changes in sediment loads will affect both the donor and recipient catchment.

The flow and sediment changes identified in the ESIAs for all HPP sites are summarized in **Table G.A.7**. Where possible, the fate of gravel and coarser sediment, sand, and silt and clay have been summarized separately. Collectively, these projects will induce large-scale changes to the Jhelum catchment as follows: Significant quantities of sand and gravel will be removed from the river system. The trap efficiency of each impoundment will vary and is related to the water velocity and sediment characteristics of the river. An example of computed trap efficiency by grain size (fall velocity) for the Neelum-Jhelum hydropower project and other Himalayan hydro projects (**Figure G.A.21**) shows that most silt is transported through impoundments, but sand trapping increases with grain size, with 100 percent of medium sand-sized and coarser material trapped.

Based on a total sediment estimate of 50 Mt/yr for the Jhelum River and the assumption that 15 percent is bedload, an average of 7.5 Mt/yr of coarse material will be trapped. This material is not readily flushed from impoundments and will be deposited within the "dead" storage area of impoundments. Once sand and gravel deposits have reached the toe of the dam wall, then the coarse material can be removed from the impoundments as bedload via low-level or sluice gates.

Figure G.A.21: Calculated Trap Efficiency by Grain Size for the Neelum-Jhelum and Other Regional HPPs



Source: Norconsult and Norplan 1997

Table G.A.7: Summary of Flow Changes and Sediment-Management Approaches for HPPs in the Neelum-Jhelum-Poonch Rivers

HPP/River	Change to upstream flow	Change to downstream flow	Change to sediment transport: gravel and coarser	Change to sediment transport: sand	Change to sediment transport: silt and clay
Kishanganga impoundment on Neelum/ discharge into upper Jhelum	7 km impoundment with 20 m operating range	Reduced by 58.4 m^3/s (avg) diversion into Jhelum when flow is sufficient; Minimum of 9 m^3/s released to the Neelum River as EFlow	Trapped and retained until equilibrium is reached with low-level outlets	"Sluiced" to downstream river without water remaining above dead- storage level; deposition in dead area until equilibrium is achieved with low-level outlets	Proportion equivalent to flow diversion is directed into Lake Wular, while the remaining is discharged into the Neelum River; some coarse silt is likely to be trapped

HPP/River	Change to upstream flow	Change to downstream flow	Change to sediment transport: gravel and coarser	Change to sediment transport: sand	Change to sediment transport: silt and clay
Neelum-Jhelum impoundment on Neelum/ discharge into lower Jhelum	Inflow reduced up to 58.4 m^3/s by the Kishanganga diversion	Reduced by 280 m^3/s diversion to the Neelum-Jhelum HPP and up to 58.4 m^3/s diversion by Kishanganga; 3 m^3/s environmental release to the Neelum River	3.4 Mt/yr is trapped in impoundment; water level is reduced in monsoon to promote deposition below active storage level; during peak flows, water level is reduced and bedload passes through large low-level outlets	3 Mt/yr is deposited within active storage level, flushed at the end of dry season via low-level outlets; up to 2.9 Mt/yr is diverted with flow to powerhouse and removed in settling basins, discharged to lower Jhelum in pulses	Diverted to powerhouse or transported through impoundment; some deposition of coarse silt in impoundment and settlement basins
Kohala impoundment on middle Jhelum/ discharge into lower Jhelum	Increased by 58.4 m^3/s (avg) as a result of the Kishanganga diversion; pattern affected by upstream HPPs	Reduced by 425 m^3/s (avg) diversion, net reduction = 366.5 m^3/s; EFlow release of 30 m^3/s to Jhelum	Accumulated until equilibrium is reached with sluice gates	Retained in reservoir, flushed when flow rate is >1,000 m^3/s; if target flow does not occur annually, conduct sediment flushing between 550–990 m^3/s	Diverted into lower Jhelum via powerhouse in proportion to water diversion; some coarse silt will likely be trapped
Balakot/Kunhar	No change to annual flow; pattern affected by two upstream HPPs	Pattern altered by HP operations; no change to annual flow	Trapped and retained until equilibrium is reached with low-level outlets	Retained and flushed annually at flow rates of 150–300 m^3/s into lower Kunhar	Discharged via powerhouse into the Kunhar River; some coarse silt will likely be trapped
Patrind impoundment on Kunhar/ discharge into lower Jhelum	Pattern affected by upstream HPPs; no change to annual flow volumes	Sept–May: discharge to lower river reduced to 2 m^3/s; other months: Discharge (Q) reduced by 153 m^3/s	Trapped and retained until equilibrium is reached with low-level outlets, then discharged into Kunhar	Retained and flushed into lower Kunhar	Diverted into lower Jhelum via powerhouse in proportion to water diversion; some coarse silt likely to be trapped
Mahl/ Lower Jhelum	Flow patterns altered by operation of upstream HPPs; upstream water level controlled by discharge from Kohala; no change to annual flow volumes	Discharge into Azad Pattan impoundment	Trapped and retained until equilibrium is reached with low-level outlets, then discharged into lower Jhelum (head of the Azad Pattan impoundment)	Retained and sluiced at flows of 1350–2000 m^3/s via sluice gates; draw-down flushing at Discharge>2,000 m^3/s via low-level outlets	Discharged via power station; some coarse silt is likely to be trapped
Azad Pattan/ Lower Jhelum	Flow patterns altered by operation of upstream HPPs; upstream water level controlled by the Mahl HPP's 22 km reservoir; no change to annual flow volumes	Discharge into the head of the Karot impoundment	Trapped and retained until equilibrium with level of low- level outlets, then flushed into lower Jhelum (head of the Karot impoundment)	Flushing via low-level gates at the start of monsoon between 500 and 1000 m^3/s	Discharged via power station; some coarse silt is likely to be trapped

HPP/River	Change to upstream flow	Change to downstream flow	Change to sediment transport: gravel and coarser	Change to sediment transport: sand	Change to sediment transport: silt and clay
Karot/ Lower Jhelum	Flow pattern altered by upstream HPPs; upstream water level controlled by the Mahl HPP's 27 km impoundment; no change to annual flow volumes	Discharge into Mangla Reservoir	Trapped and retained in impoundment until sill height is reached, then flushed with sluice gates; no low-level outlets	Trapped and retained in impoundment until sill height is reached, then flushed using sluice gates; no low-level outlets; some sand may be sluiced at minimum-operating-level water	Discharged via power station; some coarse silt is likely to be trapped
Gulpur/ Poonch	None	Up to 194 m^3/s diverted to powerhouse via tunnel, re-enters the downstream Poonch River; flow pattern modified by HPP, but annual flow volume remains unchanged	Deposited upstream of weir on the Poonch River, gravel periodically flushed	Deposited upstream of weir, periodically flushed	Diverted in proportion to flow diversion and discharged via powerhouse

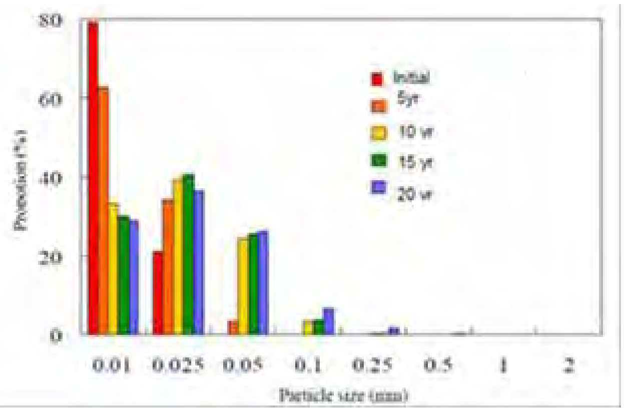
Note: Information is extracted from ESIAs and may not reflect final agreed operating conditions.

The time it will take for sand and gravel to accumulate to the point that it can be passed as bedload depends on several factors, including the rate of gravel inflow, the morphology and volume of the impoundment, the depth and configuration of flushing gates, the frequency of flushing (which can move gravel further into the impoundment), and the rate and degree of drawdown associated with flushing. Sediment-modeling results in the *Mahl Hydropower Project Feasibility Report* (SIDRI 2017) show the predicted change in grain size discharged from the dam over a 20-year period, reflecting this deposition (**Figure G.A.22**). At Mahl, it is estimated that sediment equilibrium will require around 15 years, with virtually no discharge of material greater than 0.2 mm prior to this time.

Table G.A.8 shows examples of the estimated time required for sediments to fill the dead storage of reservoirs in HPPs based on dead-storage volumes and bedload sediment inflows. These estimates reflect the duration during which the downstream environment will receive extremely low sand or gravel inputs. Flushing may accelerate the discharge of sand to some degree, but gravel will generally be retained until equilibrium is reached with the impoundment.

The pattern of sand transport in the river will be highly altered—discharge will be limited to periods of sediment flushing when sand is released in high concentrations over a short time. Although annual sand loads in the river may remain similar before and after the establishment of the HPP, little sand will be discharged for effectively 50 or more weeks of the year before the release of the annual sand load from the impoundment for a limited time. A hypothetical situation is provided in **Figure G.A.23**, where the average monthly unregulated sand loads at Patrind are compared to sand loads under a "capture-and-release" sand-flushing regime.

Figure G.A.22: Sediment Modeling Results from the Mahl Hydropower Feasibility Report Showing the Progressive Increase in Grain Size Discharged from the Project over Time



Source: SIDRI 2017
Note: The results suggest that 20 years will elapse until sediment greater than 0.25 mm (medium sand) will be discharged.

Table G.A.8: Estimated Time Required for Gravel and Coarse Sand to Achieve Equilibrium in Reservoir

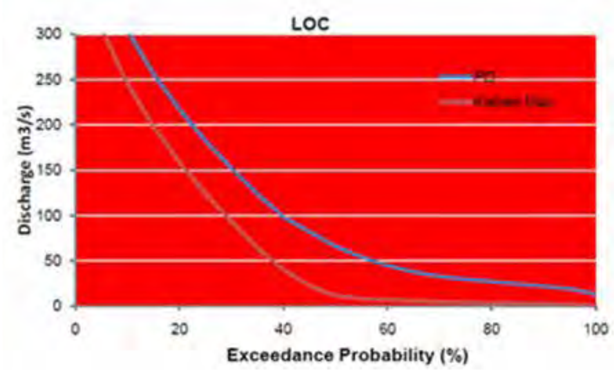
HPP	Reservoir volume	Bedload input (1.8 Mt/m³)	Estimated time to achieve equilibrium
Balakot (Mirza 2013)	Total: 12.6 Mm³ Dead: 10.04 Mm³	0.35 Mt/yr = 0.19 Mm³/yr	Around 50 years
Neelum-Jhelum (Norconsult and Norplan 1997)	Total: ~8 Mm³ Dead: 5.2 Mm³	3.4 Mt/yr = 1.8 Mm³/yr	Around 2.75 years
Kohala (BIDR 2016)	Total: 15 Mm³ Dead: Not available Assume 90% = 13.5 Mm³	5 Mt/yr = 2.8 Mm³/yr	Around five years

Note: Estimated time between dam establishment and discharge of gravel and coarse sand to downstream river.

Figure G.A.23: Hypothetical Change to Sand Delivery Based on Sand Loads at the Patrind HPP Site

Note: Based on assuming 90% sand-trapping efficiency and sediment flushing during the recession of the monsoon.

Figure G.A.24: Example of Reduction in Flow Associated with Water Diversion at the Kishanganga HPP



Source: HBP 2011

Smaller pulses of sand and silt captured in sediment traps upstream of powerhouses will be episodically flushed to the downstream river.

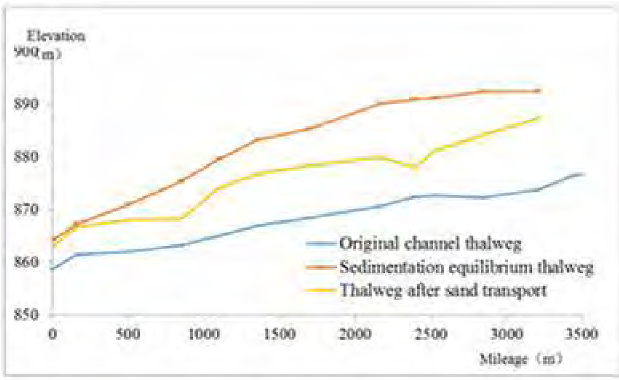
The diversions will direct equivalent proportions of silt and clay, and lesser portions of sand, as water from one river to another. These changes will alter the dispersal patterns of sediment and affect water quality in both the contributing and receiving basin.

The hydraulics of river channels will change—rivers from which water has been diverted will experience a reduction in river energy, while those receiving the water will have increased river flow and energy (**Figure G.A.24**). Of note is the confluence of the Neelum and Jhelum Rivers, which will experience a large decrease in flow, decrease in gravel delivery, and altered patterns of sand delivery. Downstream, additional changes will occur associated due to the flow diversion from the Kunhar River into the Jhelum, and the rapid increases in flow and river energy associated with the inflow from the Neelum-Jhelum and Kohala diversion projects.

Most of the projects plan to produce power continuously in the wet season but focus hydropower operations during peak periods in the winter. If each HPP adopts this pattern, the entire river will experience large water-level variations daily (or sub-daily), which will create high river-energy conditions and may exacerbate erosion across the catchment.

The sediment-management regime of most projects aims to promote sand deposition within the impoundment to minimize ingress to the turbines and wear and tear on the infrastructure. This is combined with annual sediment flushing to maintain sufficient capacity within the impoundment to provide operational flexibility. Although some sand may be flushed annually, gravel and coarser sand will not be transported downstream until an equilibrium is reached in the impoundment, whereby the deposits reach the toe of the dam and the surface of the deposits reaches the lowest outlet level. This approach will result in the deposition of deltas at the head waters of the impoundment and may increase upstream flooding during high-flow events because of reduced channel capacity. An example of the morphology of an impoundment following equilibration with gravel inputs is shown in **Figure G.A.25**. As described in the ESIA documents, all projects will trap virtually all gravel entering the impoundment. Some projects have very low-level outlets specifically to reduce the length of time until coarse material can be flushed downstream, but other projects will promote deposition until the sediment deposits reach the level of the sluice gates. As discussed previously, time-frames required to achieve equilibrium are difficult to identify and vary owing to the morphology of impoundments, rate of sediment input, and upstream activities. The loss of gravel to trapping in upstream hydropower projects or aggregate mining will reduce its availability to downstream projects, thereby taking longer to achieve equilibrium.

Figure G.A.25: Long Section of Hydropower Impoundment Showing Sand and Gravel Deposition with and without Sediment Flushing



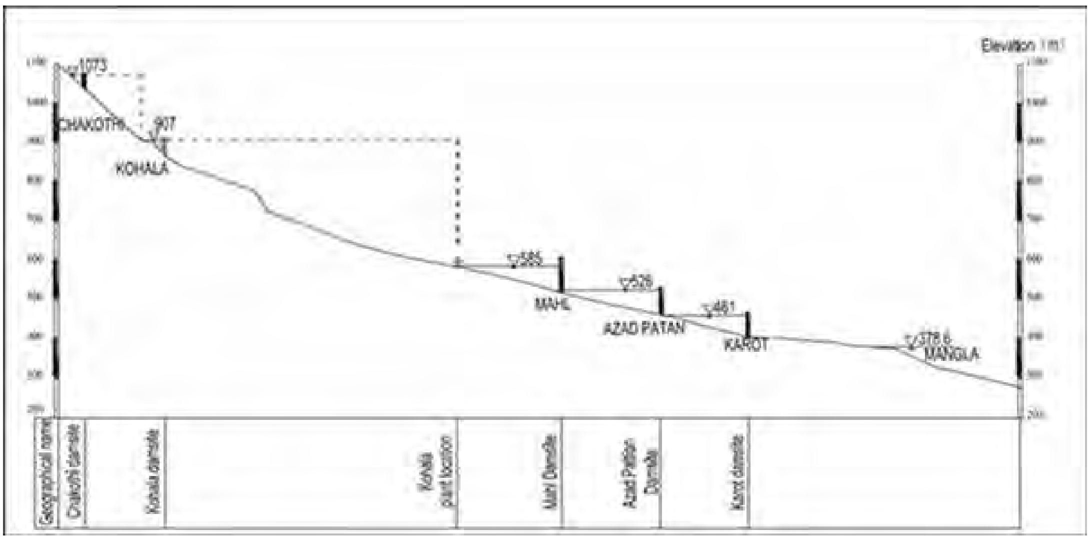
Note: Sediment deposits need to advance to the toe of the dam and base of the low-level outlet before gravel transport to the downstream river can commence.

Annual sediment flushing may negatively affect the downstream river system and HPP projects, especially in the Lower Jhelum cascade where sediment flushed from one impoundment will directly enter the next one downstream (**Figure G.A.26**). Sediment concentrations during flushing will be remarkably high; for example, it is calculated at 44 kg/m³ = 44 g/L at Kohala, well above natural sediment concentrations. These flushes may generate large turbidity plumes that propagate downstream, coating downstream riverbed and banks as well as creating hardpans on exposed riverbanks once flows recede. The nature and extent of impacts will vary with distance from the dam, the flow pattern during flushing, and flow volume and duration following the release of the large sediment load. Impacts may be mitigated if flushing coincides with high-flow events; however, such events could increase the risk of flooding downstream.

The HPP project descriptions and sediment-management approaches are largely based on average conditions, which rarely occur. Consideration needs to be given to how an impoundment will be managed in an exceedingly large sediment inflow event, such as a major landslip or avalanche. In the Jhelum Basin, the reservoirs are small compared to the “annual average” inflow-sediment volumes and they do not have capacity to store sediment loads equivalent to several “average” years. Sediment loads are highly variable and episodic events could deliver multiple times of the average load in a brief period. These situations would require more frequent flushing.

The following highlight some of the more localized geomorphic, aquatic ecology, and hydropower risks related to the implementation of flow and sediment regulation in the system.

Figure G.A.26: Schematic Diagram of the Lower Jhelum Cascade



Source: BIDR 2016
Note: The lack of “free-flowing” river sections between the projects adds complexity to sediment-flushing operations. Close coordination in the operation of HPPs is essential for successful sediment management.

Geomorphic Impacts

- The river channel immediately downstream of a dam will have a substantial risk of scour because water discharged from the dam erodes the river with no subsequent sediment deposition.
- Water diversions will reduce the sediment transport capacity of the rivers for significant lengths downstream of the diversion site for most of the year. This will reduce the grain sizes to be transported by the river, resulting in increased sedimentation. A reduction in river levels can also promote vegetation encroachment. These processes may reduce channel capacity so that when a major event occurs, flooding will occur at lower discharge rates as compared to pre-dam conditions. The risk of these processes occurring is linked to the frequency of large flood events to maintain channel capacity. Such risks are lowered if large flows are retained in the "donor" river during each monsoon season.
- Channel capacity downstream of diversion projects could also decline if accumulated sand in the impoundments is flushed into the original river channel and the river does not have sufficient energy to transport the material. There is also a risk that "flushed" material deposited on riverbanks will become cemented and affect riparian habitats. The steep nature of the river channels, high river energy, and inflow of additional tributaries can mitigate these risks if flushing coincides with high-flow periods.
- Tributaries downstream of HPPs diverting water out of catchment will be discharging into lower base levels. This will increase the water-surface slope of the tributary, river energy, and erosion in the lower channel of the tributary. The river from which water has been diverted will be able to transport less sediments and sediment inflows from tributaries may deposit and build "tributary bars" or infill the channel. The opposite situation may arise in rivers receiving additional flow, as base levels are increased and tributaries adjust to a higher base flow. The risk of impacts is related to the degree of flow change and relative inflow patterns of the tributaries and mainstem. If hydropower projects are truly run-of-river, then the relative timing and magnitude of flows in tributaries and the mainstem will not change and the risk is reduced.
- Although most impoundments are relatively small, they still extend one kilometer or more upstream. Peaking operations can create fluctuating impoundment levels of several meters per day, which may destabilize hillslopes and inhibit the establishment of riparian vegetation, leading to increased bank erosion.
- Bed-material grain size in river channels downstream of HPPs will increase because sands and gravels transported from the river channel are not replaced.

Impacts on Aquatic Ecosystems

Significant changes to the flow and sediment regime of the rivers will alter the distribution and quality of aquatic ecosystems as follows:

- A significant reduction in gravel (and larger) transport through the river systems will result in a decline in the availability of aquatic habitats. The bedload grain-size distribution results suggest that gravel is transient in the rivers, with high flows able to rapidly transport this material downstream. This suggests that any gravel habitat that was deposited at the end of the wet season will only be available in the dry season before being removed by the next high flows. Due to gravel trapping in hydropower projects, only gravel derived from the catchment downstream of HPP sites will be available for replenishment. Gravels are a key aquatic habitat for fish and a reduction in this habitat may lead to an overall decline in the fish population.
- The conversion of rivers into impoundments will alter the characteristics of the habitat, such as water depth, flow velocity, and sediment transport. Some of the impoundments in the Jhelum-Poonch catchments are relatively small, but in the lower Jhelum, the establishment of a cascade will convert 145 km of free-flowing river into four ponded storages. Upstream of the Kohala discharge point, the lower Jhelum River will have highly reduced flow and sediment transport because of the upstream diversion projects. These two impacts will fundamentally alter the habitat characteristics of the lower Jhelum River.
- Nutrient transport is linked to that of fine silts and clays and will be similarly affected as these sediment size fractions. Large quantities of nutrients will be diverted from river catchments and some will be trapped within impoundments. These changes will alter the availability of nutrients to the aquatic ecosystem and riparian vegetation.
- The flushing of sediments will create large sediment plumes that may coat and infill riverine habitats as well as blanket riparian zones with fine sediment and create hardpans. Sediment flushing can also release large volumes of low oxygen or contaminated water from the depths of the impoundments.
- The ESIAs did not provide information about sediment quality, so it is not possible to predict whether the capture or dispersal of contaminated sediments will be an issue in HPPs.

- Water quality in rivers may be affected by impoundment and intra-catchment diversions. Most proposed impoundments are relatively small with only a few days of retention time. The risk of water-column stratification in these waterbodies is low. In the lower Jhelum cascade, however, there are water-quality risks associated with the extended storage of water in successive impoundments. Light clarity will likely be high in these water bodies because of sediment settling with heightened risks of algal blooms. Water quality will likely be affected in rivers downstream of diversion projects, where the available dilution provided by river flow is substantially decreased. A potentially high-risk area is Muzaffarabad, where flow rates in the Neelum and Jhelum rivers are predicted to decrease from around 650 m^3/s to less than 100 m^3/s, reducing the available dilution for industrial, municipal, or domestic wastewater discharges by more than sixfold. This may not be an elevated risk at present, but if population growth and industrialization continue, the risk will increase.

Impacts on Other HPPs

- Sediment flushing will affect downstream rivers and HPPs. For example, the lower Jhelum River will experience large inflows of water and sediment whenever the Neelum-Jhelum, Kohala, or Patrind projects implement flushing. Simultaneous flushing by the projects may create huge sediment loads and floods in the lower river. Managing these flushes will require coordination to maintain water levels within safe limits and prevent the deposition of large sediment volumes within the lower impoundments. Flushing within the cascade (for example, from Mahl to Azad Pattan) will require similar coordination.
- If flushing coincides with high-flow events, sediment and water pulses, combined with natural inflows, may increase flooding, especially if the channel has been infilled by sediment from tributaries.
- Once the impoundments reach equilibrium with incoming bed material, flushing may become viable. In the lower cascade, the movement of large material from one project into the headwaters of the next downstream can increase bed levels and affect storage capacity.
- Flushing at the end of the wet season has been proposed to increase water-storage capacity for peaking during the dry season. This could increase sedimentation in the downstream river channel, reducing its capacity for the first high-flow events of the following monsoon season.

Summary of Findings

The terms of reference for this project posed some overarching questions regarding changes to sediment transport in the catchments:

- *Which reservoirs will trap bedload sediment?* All reservoirs are predicted to trap nearly all bedload sediment. Sediment flushing is expected to mobilize sand, but bedload comprising gravel and coarser material will remain trapped until equilibrium is achieved and the material can move downstream through a gate. Bedload transport will continue and increase in unregulated reaches of the lower rivers and abruptly end at each impoundment before recommencing downstream of the dam. However, the riverbeds downstream of impoundments will be armored as material is transported but lesser of it becomes available as bedload. This punctuated capture of material, combined with armoring of the riverbeds, will disrupt the connectivity of the river system and promote major geomorphic changes. New HPPs constructed upstream of existing projects will capture the bedload, meaning there will be less input for the downstream projects in operation. Because of this, it is difficult to determine when impoundments will achieve equilibrium with bedload transport.
- *When will hydropower projects attain equilibrium with the sediment load?* HPPs are unlikely to ever achieve a true equilibrium because of numerous factors controlling sediment transport and HPP operations. Over years to decades, a dynamic equilibrium will be reached reflecting the variability of the system, including:
  - Variable sediment loads and delivery patterns
  - Episodic extreme events resulting in the delivery of large instantaneous loads
  - The flushing regime implemented at an HPP
  - The operating regime of an HPP, which can result in the movement of material into different parts of the impoundment
  - The operations of upstream HPPs affecting bedload and sand inputs
- According to the ESIAs of hydropower projects, it usually took several decades before the active storage capacity of the impoundments reached an equilibrium with the incoming sediment load. However, these predictions were based on annual sediment loads, annual flushing, assumptions about the efficacy of flushing regimes, and catchment conditions; they did not incorporate the impacts of upstream HPPs on sediment transport. For example, the Mahl HPP is unlikely to receive its estimated sediment load of 30 metric tons per year for decades

into the future owing to the capture of material in upstream impoundments (SIDRI 2017). Therefore, time frames for achieving a sediment equilibrium within impoundments is contingent on each impoundment upstream achieving a balance.

- *How will sediment patterns change above and below each HPP?* This is summarized in **Table G.A.7**. Sediment trapping will reduce the daily transport of sand and coarser material downstream of HPPs, with episodic pulses of sand released from impoundments. Diversion projects will reduce the transport of silt and clay downstream in the donor basin and increase transport in the receiving basin. The diversion of water will also affect the transport capacity of rivers downstream of diversions, promoting large-scale geomorphic response of the river channel, such as narrowing and infilling. Sediment transport upstream of HPPs will be affected by sediment trapping and operations of existing upstream HPPs.

Information Gaps

The available sediment information provides an internally consistent, large-scale picture of sediment transport in the catchments. The most recent results were already 10 to 20 years old, so sediment- regime changes associated with catchment development or climate change over the past two decades have not been reflected in the data sets and are beyond the scope of this project. Before a robust understanding of climate-related changes could be gained, it is necessary to find out how existing hydropower stations and catchment activities have been affecting sediment transport.

While the existing information provides a catchment overview, information about local geomorphic processes is missing. These localized, reach-based relationships have a controlling influence over the biodiversity and ecosystem conditions of in-channel and riparian habitats.

A key question about sediment transport in the future is the uncertainty associated with how HPPs will operate versus how they are proposed to operate. Of particular concern is the lack of established systems to coordinate sediment flushing among different projects.

These information gaps could be addressed, at least partially, by implementing the following:

- Measure bedload movement using the Acoustic Doppler Current Profiler technology. This instrument normally measures discharge but can be adapted to calculate the average rate of bedload movement across a river profile. Other remote-sensing techniques could also be used to obtain *in situ* grain-size. These types of measurements would provide a quantitative understanding of bedload movement and sediment size that are critical for understanding sediment transport in river systems.
- Map the sediments forming in-channel habitats, such as gravel beds or sand bars, at a reach scale. This information would allow a better understanding of how these critical habitats will likely change under altered sediment-transport and flow regimes. Photo-monitoring points could be set up to take repeat photos from the same vantage point to capture changes to sediment and channel characteristics.
- Based on the river-reach maps, quantify the relationship between discharge and sediment movement, particularly reach-specific information on the sorting of sediment size-fractions to form habitats. This information is necessary to devise proper EFlow regimes.
- Gather more information about how HPPs will operate and be coordinated. The operations of HPPs will combine to produce an entirely new flow and sediment regime in the river. An understanding of the interaction of individual regimes, such as in terms of sediment flushing, is needed to identify the right management strategies. This can be done through a catchment hydropower user group or equivalent.
- Consideration should be given to the development of sediment-flushing guidelines to provide guidance on the seasonal timing of flushing, flow rates, suspended sediment concentrations, flushing durations, monitoring, and requirements for the notification of downstream communities and HPPs.

G.A.3
Updates to the Consolidated DRIFT DSS for the Jhelum-Poonch Basin

A series of updates where made to the consolidated DRIFT DSS for the Jhelum-Poonch Basin that was constructed in 2016. The most significant of these are summarized below.

Updating the Hydrological Data Using Time Series Provided by HBP

Relative to the 2016 version of the DRIFT DSS, the main changes in the hydrological modeling (HBP 2018c) include:

- Inclusion of baseload and peaking selectors within the GoldSim® model for all scenarios of the modeled hydropower projects
- Using the GoldSim® model instead of flows from a previous modeling exercise for the Neelum-Jhelum HPP

- GoldSim® model for Suki Kinari
- GoldSim® model for the Mahl HPP to produce additional peaking using storage at Mahl on top of those reported from the Neelum-Jhelum and Kohala HPPs at the Mahl Reservoir
- Patrind HPP model operating in baseload instead of peaking
- GoldSim® model for the Lower Jhelum HPP to include peaking to the extent possible; this has been under discussion for hydropower projects in Pakistan, particularly since additional flows will be available at the Lower Jhelum HPP because of the Kishanganga diversion and the possibility that the Lowe Jhelum may operate as a peaking plant (with multiple peaks during the day for example)
- GoldSim® model for Wular Lake to estimate, based on assumptions, consumptive water losses upstream because of Indian government proposals to increase water levels in the lake

Derivation of Sediment Time-Series for DRIFT

The derivation of sediment time-series for use in DRIFT was based on a combination of available sediment-transport information for the Neelum-Jhelum rivers and assumptions about how HPPs affect sediment movement in rivers. Information related to sediment loads, grain-size distributions, and timing of sediment delivery was extracted from EIAs of the HPPs in the Neelum-Jhelum catchments and summarized in a sediment audit (**Section G.A.2**). These data were used to estimate the following:

- Sediment loads and sediment yields (metric ton/km² of catchment area) for each of the subbasins: Neelum, Kunhar, middle Jhelum, lower Jhelum, and Poonch (**Figure G.A.27**)
- The monthly distribution of sediment delivery (**Figure G.A.28**)
- The grain-size distribution (gravel, sand, and silt and clay) of the annual sediment load (**Figure G.A.29**)

Figure G.A.27: Distribution of Annual Sediment Loads in the Neelum, Jhelum, and Poonch Rivers Based on Information from EIAs

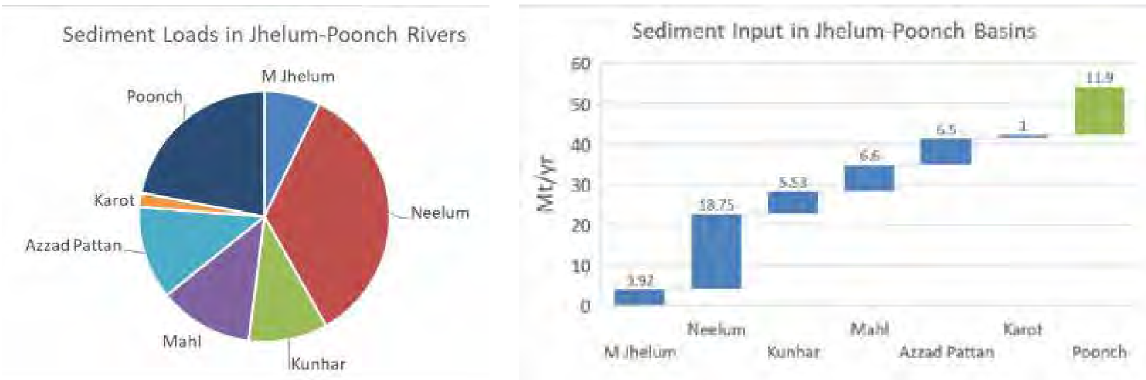


Figure G.A.28: Monthly Distribution of Sediment Loads in the Neelum, Jhelum, and Poonch Rivers Based on Information from EIAs

Figure G.A.29: Assumed Grain-Size Distribution of the Sediment Load in the Neelum, Jhelum, and Poonch Rivers

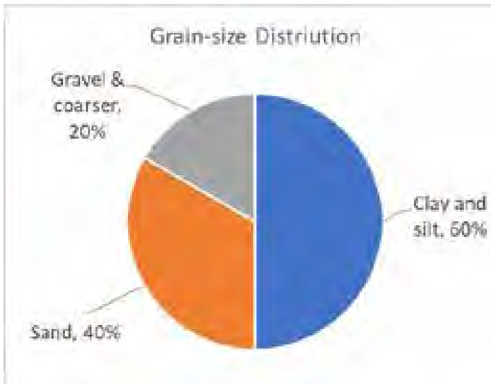
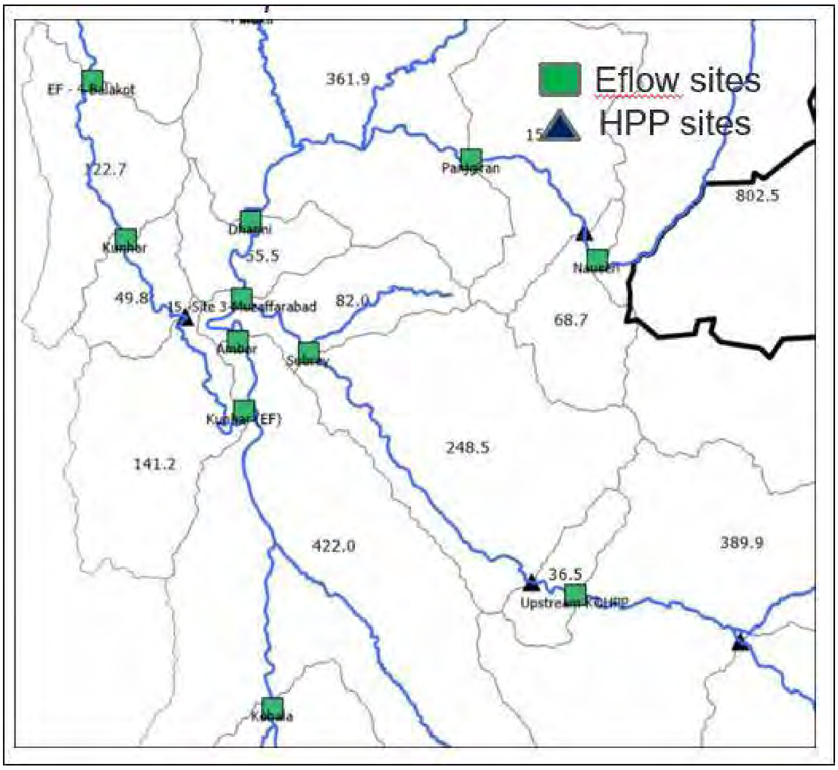


Figure G.A.30: Example of Sub-Catchment Areas Delineated by HPPs and EFlow Sites



These inputs were incorporated into a spreadsheet-sediment model with the following rules:

- Each sub-catchment was divided into numerous areas delineated by HPPs and EFlow sites (**Figure G.A.30**).
- Sediments were produced uniformly within each sub-catchment based on the catchment's sediment yields.
- The baseline scenario assumed that no HPP was present in the catchment.
- For each development scenario, sediments were routed downstream on a cumulative basis until an HPP was reached.
- At HPPs, the following rules were applied:
  - ¤ Silt and clay—not trapped and transported through the impoundment proportional to the flow rate
  - ¤ Sand—90 percent trapped annually, with 10 percent passing through
  - ¤ Gravel—100 percent trapped for at least the first 10 years of operations
- Sand flushing was assumed to occur at each HPP at the same time every year. During flushing, 90 percent of the annual sand load was discharged over a five-day period.

The spreadsheet calculated sediment loads at an annual time step, with the results distributed between months as previously described (**Figure G.A.28**). The monthly loads were divided into daily loads as inputs into DRIFT.

The EIAs also provided information about the expected rates of sediment trapping within impoundments and anticipated sediment-flushing regimes.

Sediment Flushing

Flushing is modeled as a discrete five-day event that could be allocated to any of the following four seasons: dry, transition season 1 (spring, T1), wet, and transition season 2 (fall, T2). The untested assumption is that flushing would transport the annual load of sand through an impoundment.

The pulse of sediment would undoubtedly attenuate downstream, but to what degree is uncertain. The relationship between discharge and sediment transport is poor because the river appears to have more energy than needed to transport the available sediment in most places, which means that any sediment that enters the river is transported. In the absence of detailed hydraulic information, however, it is not clear how much excess energy is available or whether it is sufficient to transport the annual sediment load in five days, although this is unlikely.

There are very few broad, low-slope areas on which a sediment pulse could deposit, so the pulse may deposit in the channel, possibly creating a temporary dam.

Eventually the flow will find a way through and an equilibrium will be established over time, whereby the flushing load is transported downstream.

To flush the full annual volume of sand, the reservoirs would need to be drawn to almost pre-dam conditions and release a lot of water. The distance the pulse travels downstream and how it attenuates will depend on the flow regime during flushing and following dam closure and refilling. The operator will also need to ensure that there is no deposition in the downstream channel that will affect tailwater levels or it will affect the efficiency of the plant, so the assumption is sufficient water will be released to move the sediment out of the immediate area. Most EFlow sites are relatively close to HPPs, so a flush event will hit them with little attenuation and probably flush past the sites.

One of the confounding factors with the current modeling of sediments is that the team used uniform annual sediment inputs, but the flow data are highly variable. This results in great variability in the onset of seasons between years and between seasonal sediment loads, even though they are uniform between some seasons.

Another variable is the grain-size distribution of the flushed sediment. This assessment uses the sand portion to illustrate flush events, although it is acknowledged that other size fractions will undoubtedly also be caught up in the flush. The effects of the gravel fraction, although not used in this phase, are captured in the DSS. The effects of the silt and clay fraction would need to be captured in the DSS.

It is possible to model attenuation using an "attenuation factor" for the flushing event and route it downstream over the next year in proportion to flow, but this has not been done in this phase of the DSS adjustments. For example, 60 percent of the load could be sent downstream as a pulse and the remaining 40 percent added to the monthly loads of the following wet season. At this stage, keeping it as a single pulse in DRIFT highlights the erosion expected to occur during the non-flushing season and the large depositions expected to occur during the flush. That said, the response curves for sediment in each season do account for this, albeit qualitatively. If flushing occurs in T1 or during the wet season, the response curves assume that the elevated wet-season flows would transport available sediment through the reach, whereas in T2 and the dry season, they assume that flow will be insufficient and sediment will settle in the reach.

Non-HPP Pressure Indicators

In the last phase of the Jhelum DRIFT DSS work, non-HPP pressure indicators, such as fishing or sediment mining, were added to the Kishanganga and Neelum-Jhelum HPP sites (and the eight additional sites) to bring them in line with work done for the Gulpur HPP, Karot HPP and Kohala HPP (**Table G.A.1**).

The six non-HPP-related pressures incorporated into the DSS are:

1. Fishing pressure—selective (linked to all fish indicators)
2. Fishing pressure—non-selective (linked to all fish and invertebrate indicators)
3. Mining—cobble and boulder (linked to relevant geomorphological indicators)
4. Mining—sand and gravel (linked to relevant geomorphological indicators)
5. Nutrient enrichment—mainly because of sewage effluent (linked to relevant water-quality indicators)
6. Tree cutting—harvesting of riparian bushes and trees (linked to vegetation indicators)

These reside as response curves under each relevant indicator. Selective fishing, for instance, appears as a response curve under each fish indicator, its shape reflecting current understanding of the original abundance of the indicator, its present abundance, and its expected abundance under different protection measures (end values). Non-selective fishing, on the other hand, will also have a response curve for aquatic invertebrates as they can be affected by pressures such as explosives or poisons.

The end values were decided in team consultations and are detailed together with their explanation in the supporting documentation for individual studies, for example, the EFlow assessments for the Gulpur HPP, the Karot HPP, and the Kohala HPP. Essentially, the relevant experts were asked how the abundance of each indicator has changed (if at all) from its condition at some time in the past (such as 30 years ago) and what were the main drivers of change. They were also asked what abundance level they would expect it to reach in the future under various protection levels as follows:

- Business as usual (BAU) = a gradual increase in 2013 pressures from 100 percent in 2013 to 200 percent over 30 years
- Pro 1 = 2013 pressures fixed for the next 30 years
- Pro 2 = 2013 pressures halved over the next five years and then stable at that level for the next 25 years
- Pro 3 = reduce 2015 levels of non-flow-related pressures by 90 percent, that is, decline in pressures, relative to 2015, over time (only applied for the Kohala HPP)

In this phase, these response curves were reviewed and adjusted slightly to ensure that all subbasins could be run at BAU, Pro 1, or Pro 2. Details on the management activities underlying Protection Level 1 and 2 are provided in HBP et al. (2014). Those underlying Protection Level 3, which is only relevant for the areas to be managed under the Kohala HPP Biodiversity Action Plan, are provided in HBP and Southern Waters (2015b).

Other Adjustments

The researcher revised all the response curves for geomorphology indicators with the following aim:

- To include the new sediment data (at seasonal level)
- To ensure that the handling of geomorphology was consistent across all sites in the DSS

In the DSS, sites are linked to a ***single*** upstream site for sediment load. For instance, Ambor is linked to Muzaffarabad but not to Kunhar or Subrey. The reason for this is that adding links to additional sites would not substantially improve (or even change) the DSS outputs at the basin scale, but it would increase the complexity of the DSS and the speed with which it opens and runs, particularly on older computers.

The researcher also revised the response curves for links to sediment for other indicators, such as macroinvertebrates, fish, and water quality to ensure that they reflected the updated sediment data and captured the predicted effects of sediment flushing.

Numerous other adjustments were made to the DSS to incorporate new data as well as synchronize the indicators and linked indicators at the various sites. While there are still some differences in the assessment indicators and linked indicators that are not related to natural differences between the sites, most of these have now been rationalized.

Other significant changes include:

- Changing “water temperature” to “winter water temperature” and adding an indicator called “summer water temperature,” with the necessary adjustments to links to other indicators, such as fish[4]
- Deleting active channel width—this indicator was inherited from the Kishanganga study and has proved problematic to calibrate throughout because there were insufficient hydraulic data to assess channel dynamics
- Changing “exposed cobble and boulder bars” to “cobble bars and areas” because the “exposed” part of the indicator name resulted in a conflation of two opposing influences in the dewatered areas:
    - ¤ A reduction in the availability of cobble because of trapping in HPPs
    - ¤ An increase in “exposure” of bars because of reduced flows
- Changing “exposed sand and gravel bars”’ to “sand and gravel bars and areas” for similar reasons above

G.A.4
Training and Testing Workshop

A Jhelum-Poonch basin-wide DSS training and testing workshop was held at the offices of Hagler Bailly Pakistan in Islamabad from January 23–25, 2018. A list of the participants and a summary of the agenda are provided below. A list of participants (**Table G.A.9**)

Participants

Facilitators: Alison Joubert, Cate Brown, Vaqar Zakaria, and Hassan Bukhari

Table G.A.9: List of Participants

Organization	Name	Designation
Kohala Hydropower Company Ltd.	Sahibzada Tanzeel Ahmad	Manager, Environment and Social
Forest, Fisheries and Wildlife Department, Punjab	Maratab Ali Awan	Assistant Director, Fisheries
Climate Change Department, Azad Jammu and Kashmir	Syed Rashid Hussain Shah	Director, Climate Change Centre
Environmental Protection Agency, Azad Jammu and Kashmir	M Ali Saleem	Assistant Director, EPA
Environmental Protection Agency, Azad Jammu and Kashmir	Shafiq Abbasi	Director, EPA
Environmental Protection Agency, Khyber Pakhtunkhwa	Mohammad Ali Khan	Deputy Director, EPA Head Office
S A N Engineering, Nepal	Narayan Rijal	CEO
Environmental Protection Agency, Khyber Pakhtunkhwa	Amjad Ali	Director (IV)
Hagler Bailly Pakistan	Ahmad Shoaib	Fisheries Specialist
Hagler Bailly Pakistan	Anusha Nisar	Environmental Engineer

[4] The DSS excludes consideration of a temperature change in the lower Jhelum River as a result of the release from the Kohala tailrace. This is unlikely to be a major effect.

Day 1: Tuesday, January 23, 2018

8:30 a.m.	Welcome and Introductions	Vaqar Zakaria
8:45 a.m.	Introduction to the Workshop—Aims and Agenda	Cate Brown
9:00 a.m.	HPPs: Flows, Sediments, and Fish	Cate Brown
9:30 a.m.	Introduction to DRIFT	Cate Brown
10:00 a.m.	TEA	Director, EPA
10:30 a.m.	Loading the Jhelum DSS onto Personal Computers	Alison Joubert
	Introduction to the Jhelum DSS	
	Navigating the DSS	
12:30 p.m.	LUNCH	
1:30 p.m.	Guidance on the DSS: Geomorphology Indicators and Response Curves	Cate Brown
2:00 p.m.	Guidance on the DSS: Fish Indicators and Response Curves	Alison Joubert
2:30 p.m.	Hands-on Exploring the DSS	All
3:00 p.m.	TEA	
3:30 p.m.	Working Session Familiarization of the DSS—Indicators and Links Tasks	All
4:30 p.m.	Close of the Day	

Day 2: Wednesday, January 24, 2018

8:30 a.m.	Revised Agenda	Cate Brown
8:40 a.m.	Report-Back on Indicator Tasks	2 minutes each
10:00 a.m.	Overall Integrity—Concept and Calculation	Cate Brown
10:30 a.m.	TEA	
11:00 a.m.	Introducing Testing Scenarios	Cate Brown
11:30 a.m.	Excel Summary File	Alison Joubert
1:00 p.m.	LUNCH	
2:30 p.m.	Review of Testing Scenarios	Alison Joubert
3:00 p.m.	Review of Testing Scenarios: in Groups with Assistance	
3:30 p.m.	Close of the Day	

Day 3: Thursday, January 25, 2018

9:30 a.m.	World Bank Good Practice Note: EFlow Assessments for Hydropower Projects	Cate Brown
10:00 a.m.	DRIFT Applications Elsewhere in the World	Cate Brown
10:30 a.m.	TEA	
11:00 a.m.	DRIFT Applications in the Neelum-Jhelum Basin: Lessons Learned	Vaqar Zakaria
1:00 p.m.	LUNCH	
2:00 p.m.	Comments and Suggestions from Participants	
3:00 p.m.	Discussion—Scenarios for Assessment Use of the Neelum-Jhelum Basin-Wide DSS and If/When It Could Be Most Valuable	Vaqar Zakaria/ Cate Brown
3:30 p.m.	Close of the Day	

Comments and Suggestions from Participants

The comments and suggestions are provided in **Table G.A.10**. Each of these was discussed in the workshop; summaries of the discussion are also provided in **Table G.A.10**.

Table G.A.10: Workshop Comments and Suggestions

	Comments and suggestions	Discussion
1.	The DRIFT DSS should be expanded to include social aspects.	DRIFT has provision for inclusion of social aspects, but in some cases, such as Gulpur, the complexity of these meant they were better dealt with separately based on DRIFT results.
2.	Additional training is required to master running DRIFT.	Noted
3.	The effects of mining should be included in the DRIFT DSS.	The effects of mining are included in the Neelum-Jhelum basin-wide DSS under the “management” discipline.
4.	The DRIFT DSS should include options for improving the livelihoods of the people in the basin.	See above
5.	The DRIFT DSS should include the effect of municipal solid waste.	Noted
6.	It is important to maintain close consultation with fishery departments.	This has been done extensively in AJK and in Punjab and KP to some extent.
7.	Consideration should be given to researching/ introducing exotic species to the rivers and reservoirs to replace lost indigenous species (fish).	The Institute for Research on River Ecology proposed at Kohala could address issues such as this.
8.	Training should include more practical work.	Noted
9.	Line department in other areas (other river basins), particularly those in the north, should be drawn into the DRIFT/EFlow information transfer and training activities because HPPs are planned there as well.	Noted
10.	It is expected that there will be a lot of controversy once the HPPs begin operation, so it is important to set up comprehensive monitoring programs as soon as possible to check outputs of modeling and management activities.	Agreed
11.	As the regulator, we need to look for areas where we can leverage better environmental and social performance from HPPs. DRIFT has assisted with this. The CIA should have been done earlier.	There have been various versions of CIA done for the Neelum-Jhelum Basin. However, it is agreed that using these to guide development should have been done earlier.
12.	All EFlow assessments should be done at the basin scale. It is pointless doing them at an individual-project scale.	Agreed that basin-scale studies are more useful; however, with DRIFT, studies are done at the first available level and built from there.

G.A.5
Results of Scenario Analysis

Scenarios Assessed

The scenarios selected for assessment comprises permutations of the presence of HPPs (**Table G.A.11**), which incorporate:

- Levels of management aimed at reducing non-HPP impacts on the river ecosystem (protection levels), as follows:
  - ¤ Agreed management
  - ¤ High management
- EFlow releases, where known and applicable (**Table G.A.11**)
- Sediment trapping and sediment flushing, namely:
  - ¤ Sediment flushing in April
  - ¤ Sediment flushing in August
- Barrier effects of HPPs on migration of fish, as follows:
  - ¤ Upstream barrier 100 percent reduction in fish passage
  - ¤ Downstream barrier = 95 percent reduction in fish passage
- Peak-power or baseflow operation of HPPs (**Table G.A.11**)

The two management levels are defined by peak-power or baseload power generation, the EFlow releases outlined in **Table G.A.11**, and the various management levels agreed with HPP companies outlined in **Table G.A.12**. In essence, “high management” offers stronger protection levels than the agreed protection levels implemented throughout the basin; examples include higher EFlow releases (22.5 m^3/s instead of 9 m^3/s) from the Neelum-Jhelum HPP and baseload instead of peaking operations at the Neelum-Jhelum and the Kishanganga HPPs.

The 2016 DRIFT modeling, including use of the updated sediment data, was not redone for the Poonch Basin and the results were not updated.

Table G.A.11: Scenarios Assessed in this Report

Subbasin	HPP	Existing and under-construction		Committed		Planned	
		Agreed management	High management	Agreed management	High management	Agreed management	High management
Neelum	Kishanganga	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s
	Dudhnial					Baseload	Baseload
	Ashkot					Baseload	Baseload
	Athmuqam			Baseload	Baseload	Baseload	Baseload
	Neelum-Jhelum	Peaking EFlow release (9 m^3/s)	Baseload/higher EFlow release (22.5 m^3/s)	Peaking EFlow release (9 m^3/s)	Baseload/higher EFlow release (22.5 m^3/s)	Peaking EFlow release (9 m^3/s)	Baseload/higher EFlow release (22.5 m^3/s)
Kunhar	Suki Kinari	Peaking	Peaking	Peaking	Peaking	Peaking	Peaking
	Balakot			Baseload	Baseload	Baseload	Baseload
	Patrind	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
Upper Jhelum	Wular					Baseload	Baseload
	Lower Jhelum	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Uri I	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Uri II	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
	Chakothi-Hattian					Baseload	Baseload
Upper Jhelum	Kohala	Peaking EFlow release (30 m^3/s)	Baseload EFlow release (30 m^3/s)	Peaking EFlow release (30 m^3/s)	Baseload EFlow release (30 m^3/s)	Peaking EFlow release (30 m^3/s)	Baseload EFlow release (30 m^3/s)
Lower Jhelum	Mahl			Peaking	Baseload	Peaking	Baseload
	Azad-Pattan			Baseload	Baseload	Baseload	Baseload
	Karot	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
Poonch	Parnai			Baseload	Baseload	Baseload	Baseload
	Sehra			Baseload	Baseload	Baseload	Baseload
	Gulpur	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload

Table G.A.12: Protection Levels Applied for River Reach Represented by Each EFlow Site

River reach represented by			Agreed management	High management
Neelum	1	Line of Control	Pro 1	Pro 1
	2	Surgun Nullah	Pro 1	Pro 1
	3	Dudhnial	Pro 1	Pro 1
	4	Athmuqam	Pro 1	Pro 1
	5	Jagran Nullah	Pro 1	Pro 1
	6	Nauseri (0)	Business as usual	Pro 2
	7	Panjgiran	Business as usual	Pro 2
	8	Patikka Nullah	Business as usual	Pro 2
	9	Dhanni	Business as usual	Pro 2
	10	Muzaffarabad	Business as usual	Pro 2
Upper Jhelum	11	Upstream KHPP	Pro 3	Pro 3
	12	Subrey	Pro 3	Pro 3
Kunhar	13	Khanian	Business as usual	Pro 2
	14	Paksair	Business as usual	Pro 2
Lower Jhelum	15	Ambor-5	Pro 3	Pro 3
	16	Kohala-6	Business as usual	Pro 2
	17	Mahl Nullah	Business as usual	Pro 3
	18	Mahl DS	Business as usual	Pro 2
	19	Azad Pattan	Business as usual	Pro 2
	20	Kahuta Nullah	Pro 2	Pro 2
	21	Hollar-7	Pro 2	Pro 2
Poonch	22	Kallar Bridge	Pro 2	Pro 3
	23	Borali Bridge	Pro 2	Pro 3
	24	Gulpur Bridge	Pro 2	Pro 3
	25	Billiporian Bridge	Pro 2	Pro 3

Note: Pro 1 = 2013 pressures fixed for the next 30 years; Pro 2 = 2013 pressures halved over the next five years and then stable at that level for the next 25 years; Pro 3 = reduce 2015 levels of non-flow-related pressures by 90 percent, that is, decline in pressures (relative to 2015) over time (only applied for Kohala HPP).

G.A.6 Scenario Results

For each scenario, predicted changes in the river ecosystem are presented as a change in overall ecosystem integrity relative to baseline (BASE 2012 Pro 1)[5] for the river reach represented by each EFlow site. Ecosystem integrity is classified using categories A to F (**Figure G.A.31**).

The DSS provides estimated mean percentage change from baseline in the abundance, area, or concentration of the indicators (these are tabulated in **Annex G**). Integrity ratings were calculated by assigning a positive or negative sign to changes in abundance depending on whether an increase in abundance is a move toward or away from the natural condition. The integrity ratings for each indicator were then combined to provide an overall ecosystem integrity.

[5] See **Non-HPP Pressure Indicators** in **Section G.A.3** for an explanation of "Pro 1" and other protection levels.

Figure G.A.31: Ecological Integrity Ratings

Ecological category	Corresponding DRIFT integrity	Description of the habitat
A	>−0.25	Unmodified: the habitat is still in a natural condition.
B	>−0.75	Slightly modified: a small change in natural habitats and biota has taken place, but the ecosystem functions have essentially remained the same.
C	>−1.5	Moderately modified: loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	>−2.5	Largely modified: a large loss of natural habitat, biota, and basic ecosystem functions has occurred.
E	>−3.5	Seriously modified: the loss of natural habitat, biota, and basic ecosystem functions is extensive.
F	<−3.5	Critically/extremely modified: the system has been critically modified with an almost complete loss of natural habitat and biota; in the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

Source: Kleynhans 1996; Brown and Joubert 2003

The overall ecosystem integrity for each EFlow reach associated with each scenario is summarized in **Table G.A.13** and shown in **Figure G.A.32** to **Figure G.A.41**.

Overall, the gradual increase in the number of hydropower projects in the Jhelum-Poonch Basin will be accompanied by:

- A decline in sand and gravel availability in the rivers—this may be partially offset by the flushing of sand-sized sediments, but gravels cannot be flushed from the reservoirs for many years.
- An increase in the availability of cobble and boulders—this is mainly because they will become exposed as sands and gravels are eroded and not replaced because they are trapped in upstream reservoirs.
- This effect is unlikely to persist for a great distance downstream of any single HPP, particularly in the upper parts of the basin, because of the high sediment supply from the hillslopes (landslides). It may be more problematic downstream, where less sediment is supplied by the slopes and the cumulative impacts of many HPPs has a greater effect on supply.
- Reduced habitat diversity is directly linked to lower sediment supply and increased erosion. This will likely affect breeding habitats, as many spawning fish tend to favor gravel habitats.
- Changes in habitats and the knock-on effects on other aspects of the river ecosystem, such as downstream riparian vegetation and macroinvertebrates that provide much of the fish food, will reduce fish abundance.
- Sediment flushing will unlikely alleviate the negative impacts because it results in large and simultaneous supplies of sediments that are difficult to sort or move downstream. The net effect is often localized smothering of habitats rather than a reset to more natural sediment-supply levels in a whole river reach.
- The large migratory fish species, such as the brown trout and golden mahseer, will be particularly hard hit as the insurmountable HPP weirs will lead to a progressive decline in their home range.
- It is worth noting that the proposed HPPs all have extensive reservoirs, which will result in deeper, lake-like habitat unsuitable for colonization by most river species. This will significantly transform the nature of the aquatic ecosystems in the Jhelum-Poonch Basin.

Table G.A.13: Overall Ecosystem Integrity for Each EFlow Reach of Each Scenario

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) Business As Usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Neelum	Line of Control	B/C	C	D	D	D	D	D	D	D	D
	Surgun Nullah	B	C	C	C	C	C	C	C	C	C
	Dudhnial	B/C	C	C	C	C	C/D	C	C	D	D
	Athmuqam	C	D	D	D	D	D	D	D	D	D
	Jagran Nullah	B/C	D	C	C	C	C	C	C	C	C
	Nauseri	C	D	D	C	C	C/D	D	C/D	D/E	D
	Panjgiran	C	D	E	D	D/E	D	E	D	E	D
	Pattika Nullah	C	D	D/E	C	C/D	C/D	D/E	C	D/E	C
	Dhanni	C	D	E	C	D/E	D	E	D	E	D
	Muzaffarabad	D	E	E	E	E	E	E	E	E	E
Upper Jhelum	Upstream Kohala HPP	C	D	B	B	B/C	B/C	B	B	B/C	B/C
	Subrey	C	D	C/D	C	D	C/D	C/D	C	C/D	C/D
Kunhar	Khanian	C	D	E	D	D	D	E	D	E	D
	Paksair	C	D	E	C/D	D	D	E	D	E	D
Lower Jhelum	Ambor	C/D	E	E	D/E	E	E	E	E	E	E
	Kohala	C/D	D/E	E	D	D/E	D/E	E	D	E	D
	Mahl Nullah	C	D	D	B	B/C	B/C	D	C	D	C
	Mahl DS	C	D	E	D	D	D	E	D	E	D
	Azad Pattan	C	D	E	D/E	E	E	E	E	E	E
	Kahuta Nullah	C	D	C	C	C	C	C	C	C	C
	Hollar	C	D	D	D	D	D	E	D	E	D
Poonch	Kallar Bridge	C	D	C				C		D	
	Borali Bridge	C	D/E	D				D		D	
	Gulpur Bridge	C	D/E	C		Not run		C	Not run	C	Not run
	Billiporian Bridge	C	D/E	B/C				B/C		B/C	

Note: SF-4 = April sediment flush; SF-8 = August sediment flush

Figure G.A.32: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Baseline (2012)

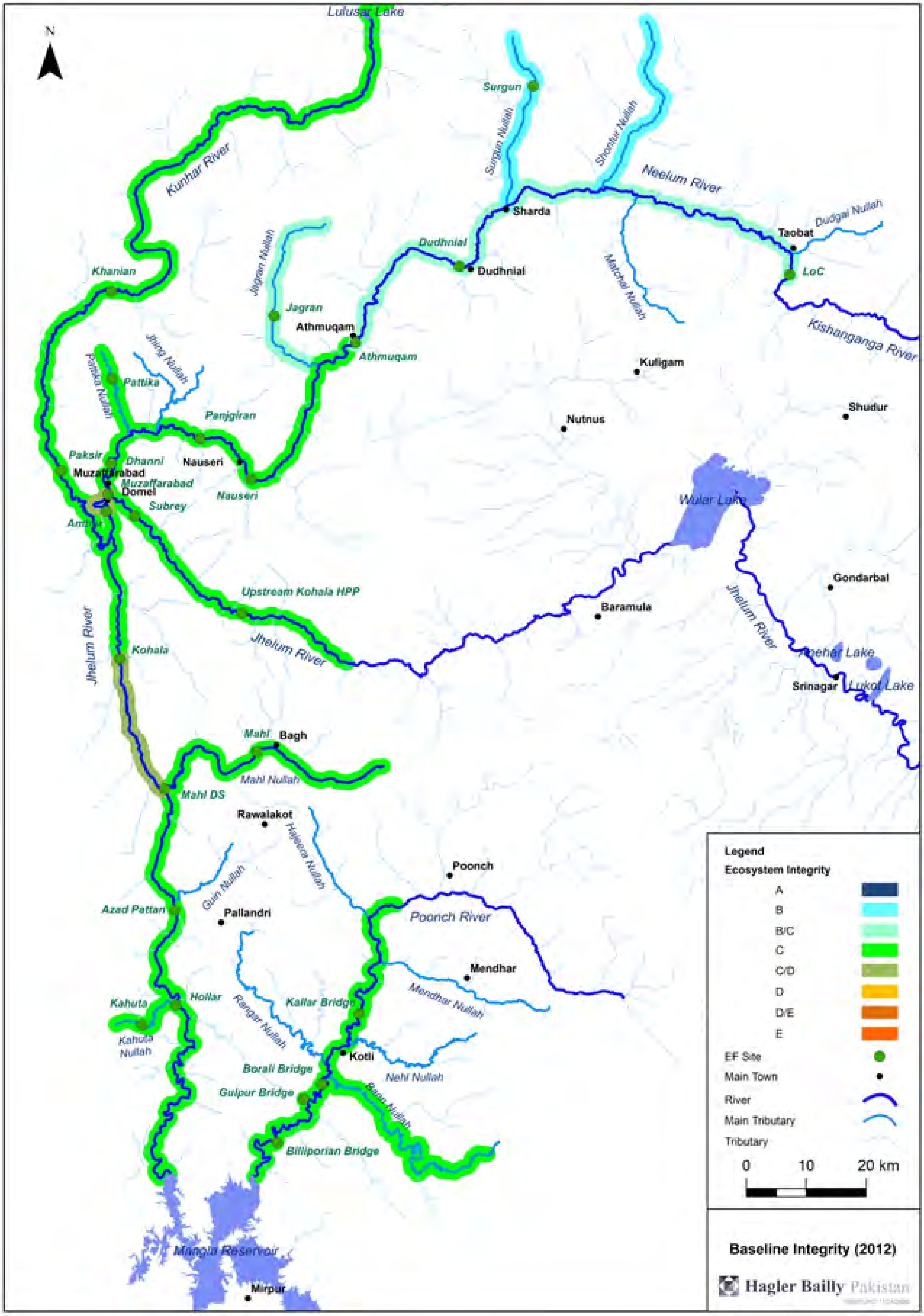


Figure G.A.33: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under the Baseline (2012): Business-as-Usual Scenario

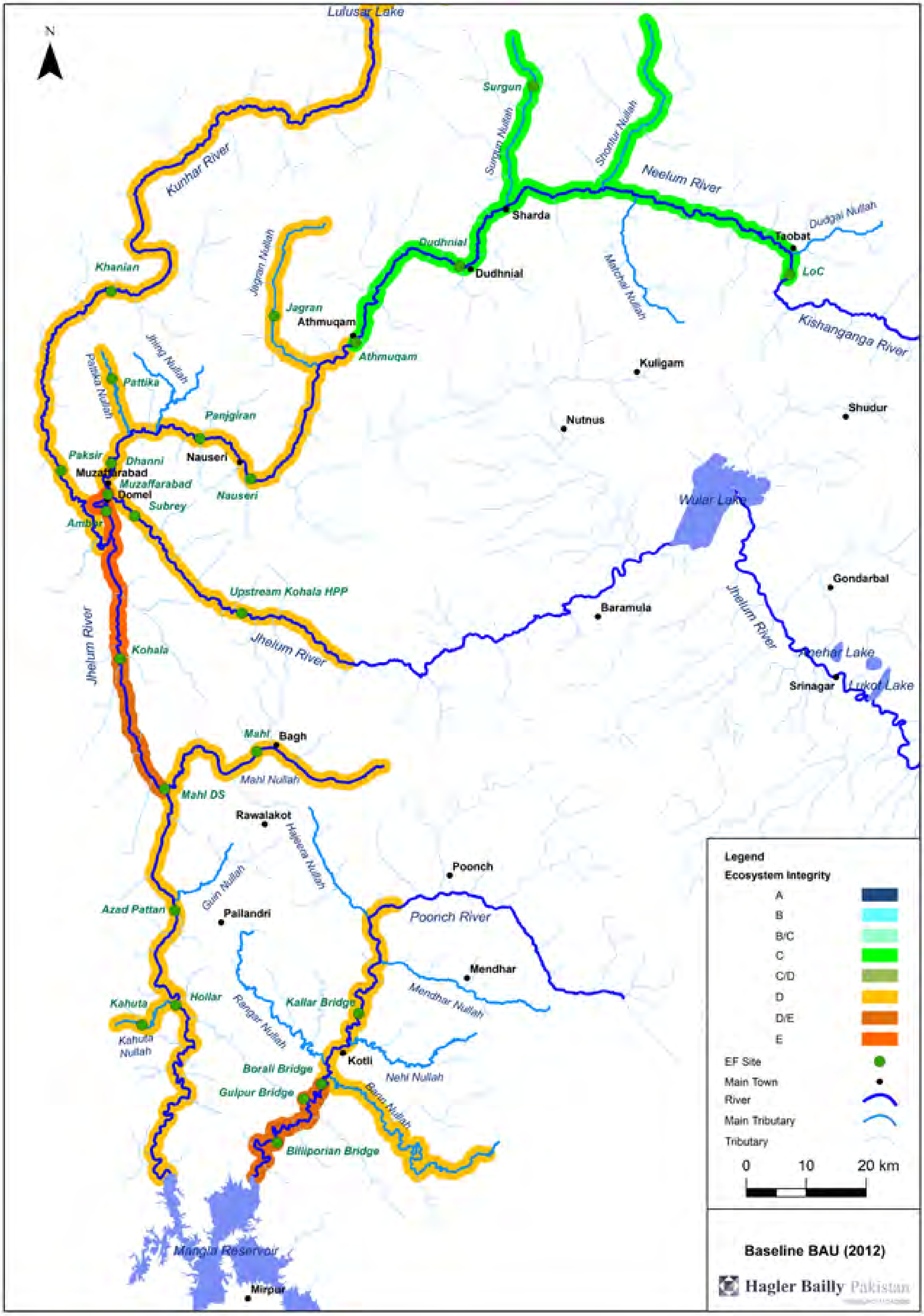


Figure G.A.34: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Existing and Under-Construction: Agreed Management

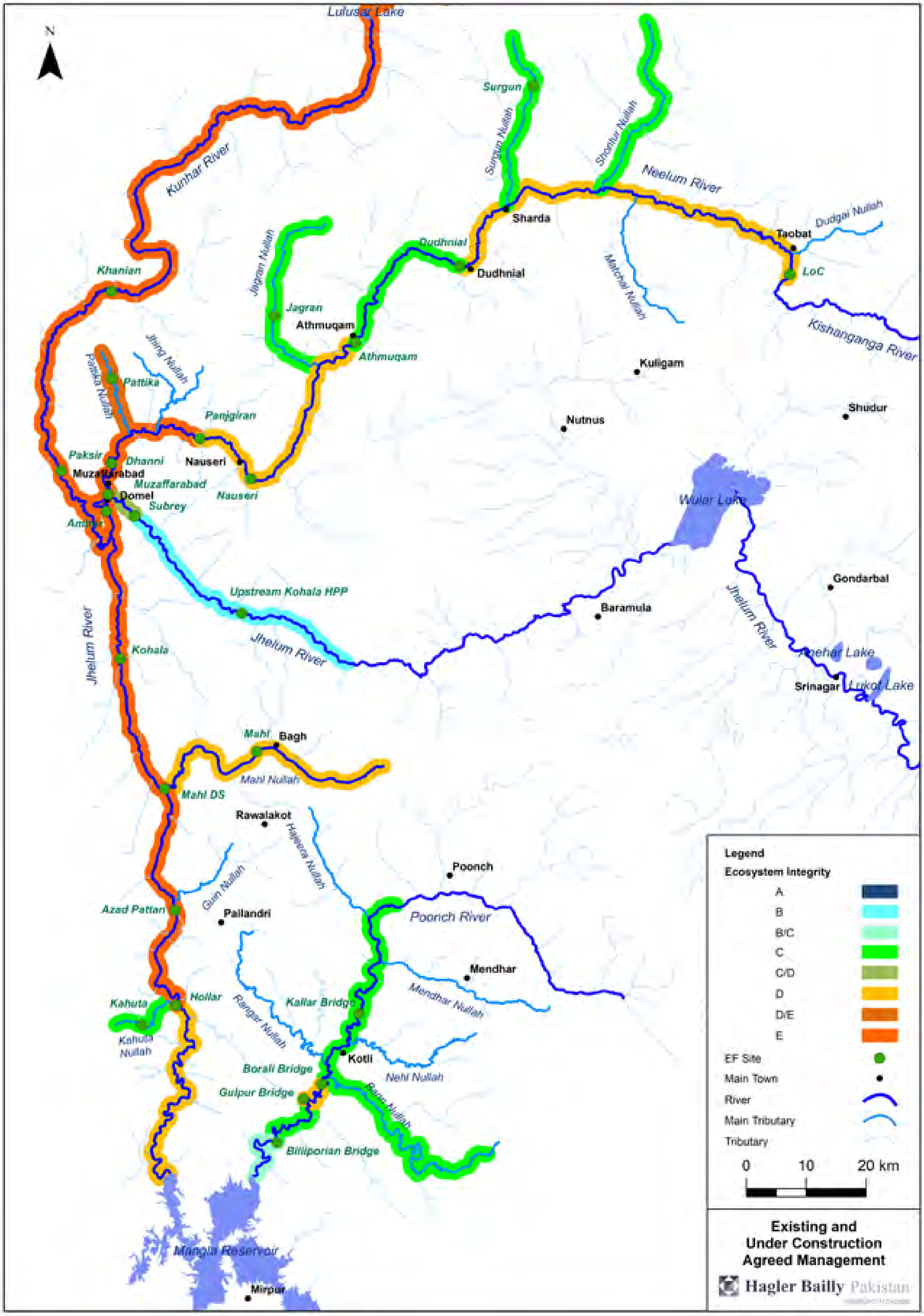


Figure G.A.35: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Existing and Under-Construction: High Management

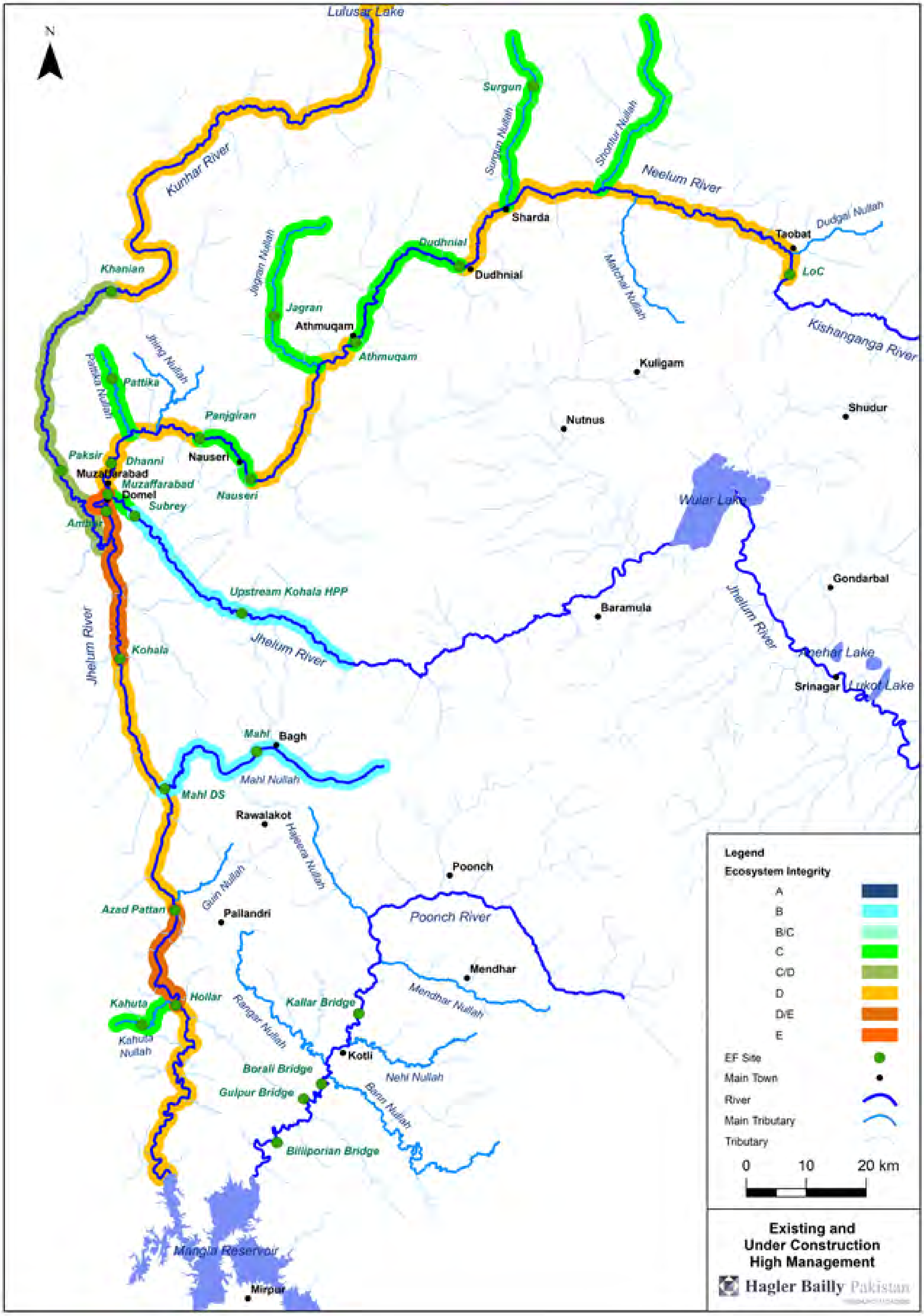


Figure G.A.36: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Existing and Under-Construction: High Management with Sediment Flushing in March or April

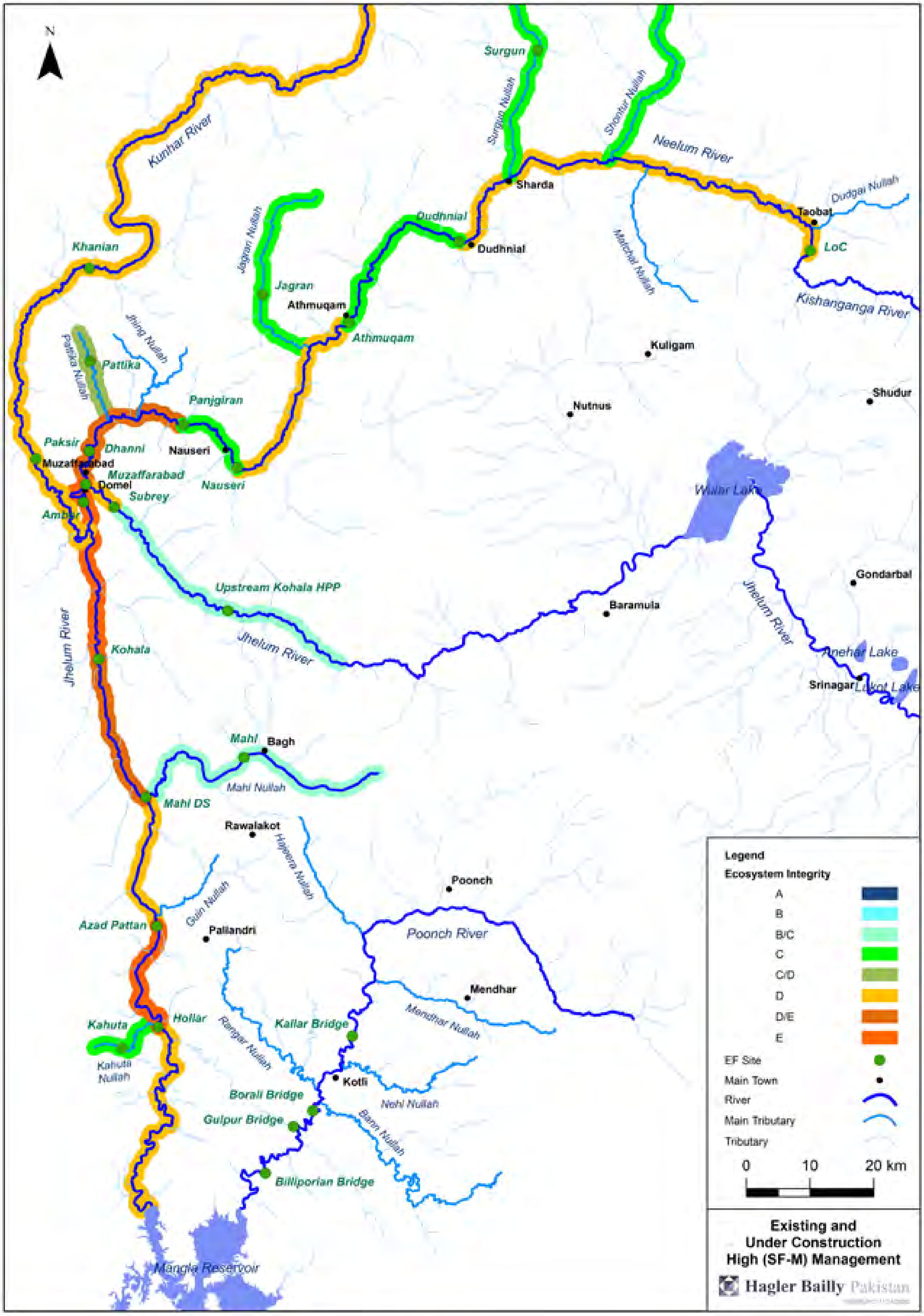


Figure G.A.37: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Existing and Under-Construction: High Management with Sediment Flushing in August

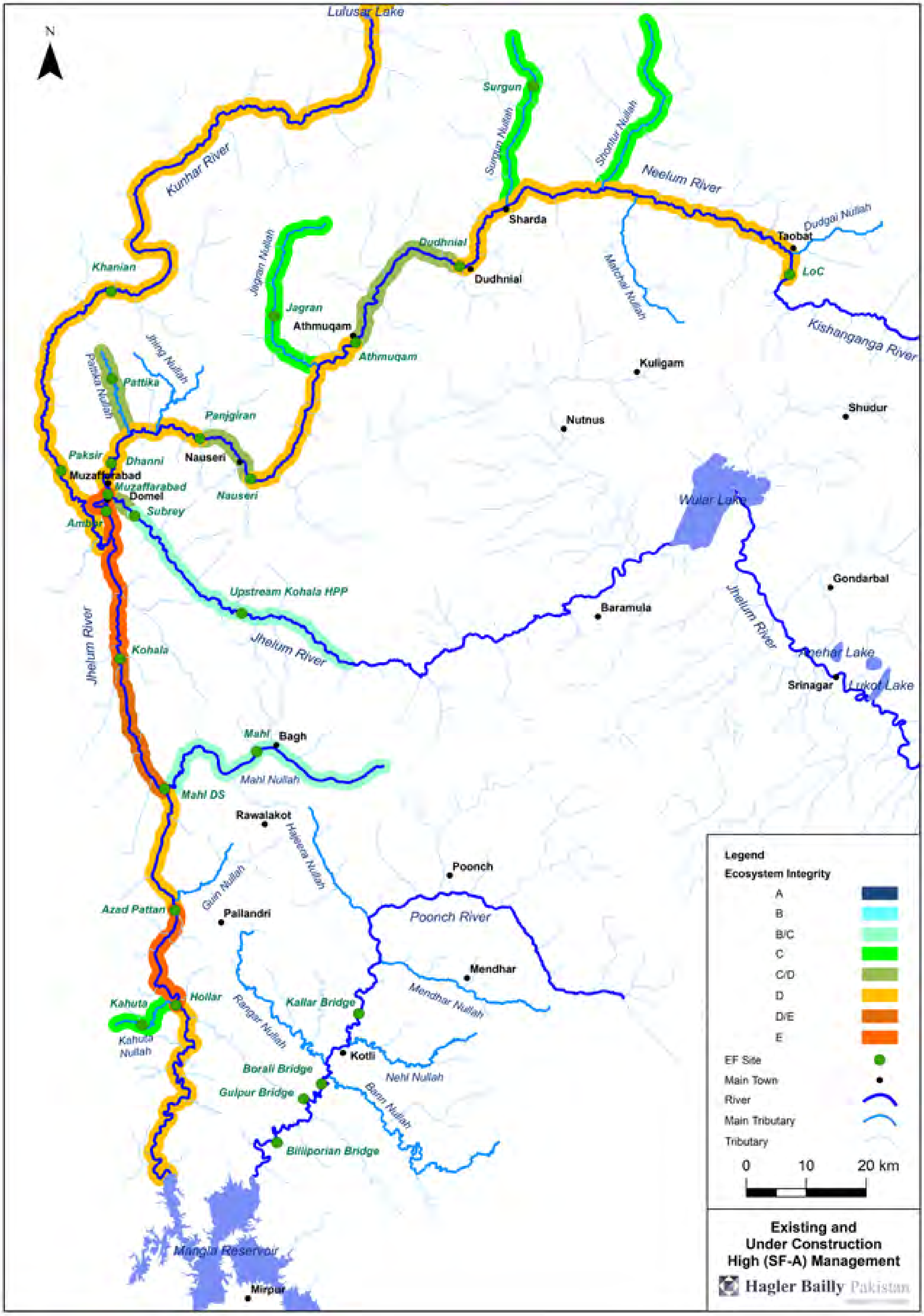


Figure G.A.38: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Committed: Agreed Management

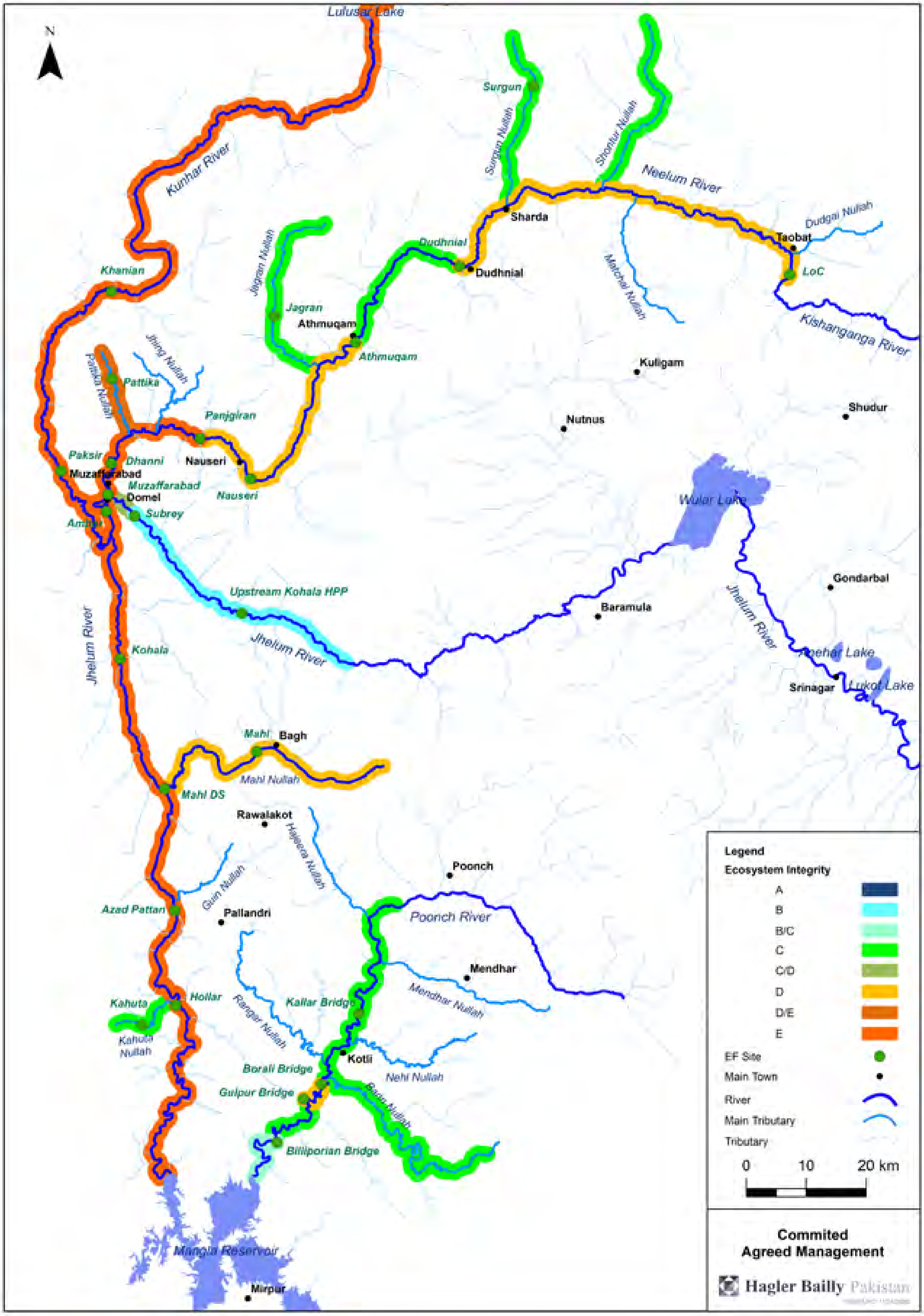


Figure G.A.39: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Committed: High Management

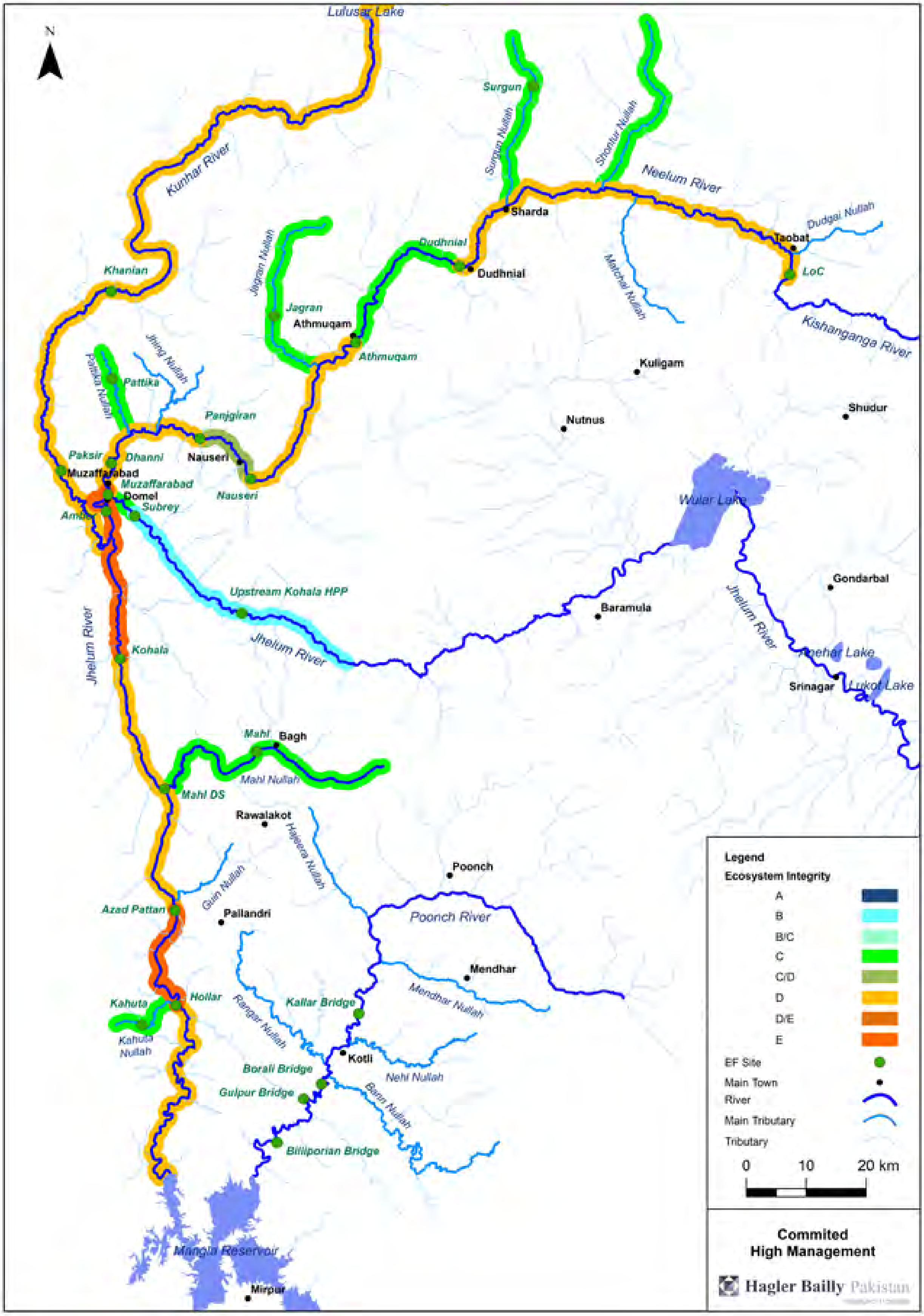


Figure G.A.40: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Planned: Agreed Management

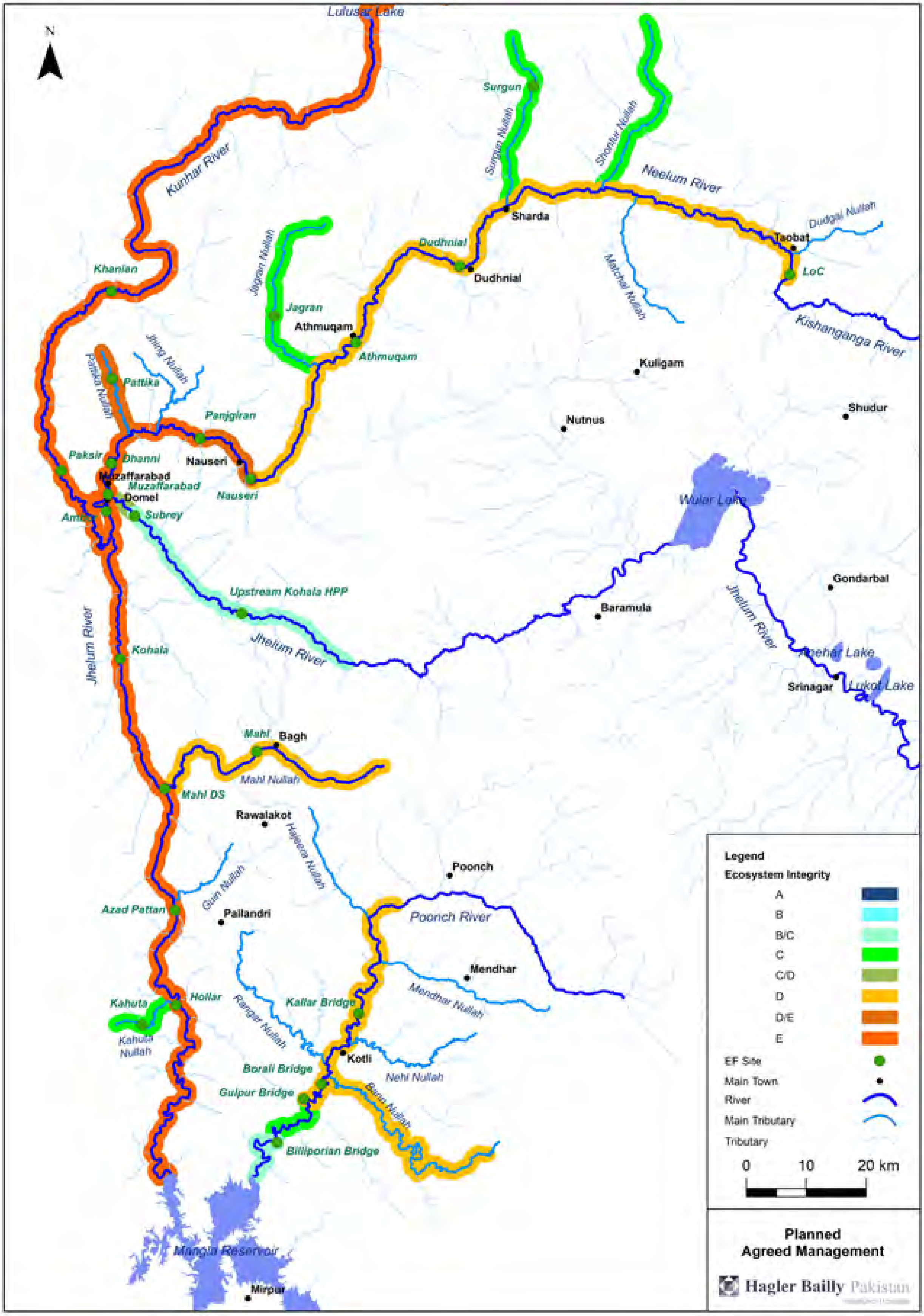
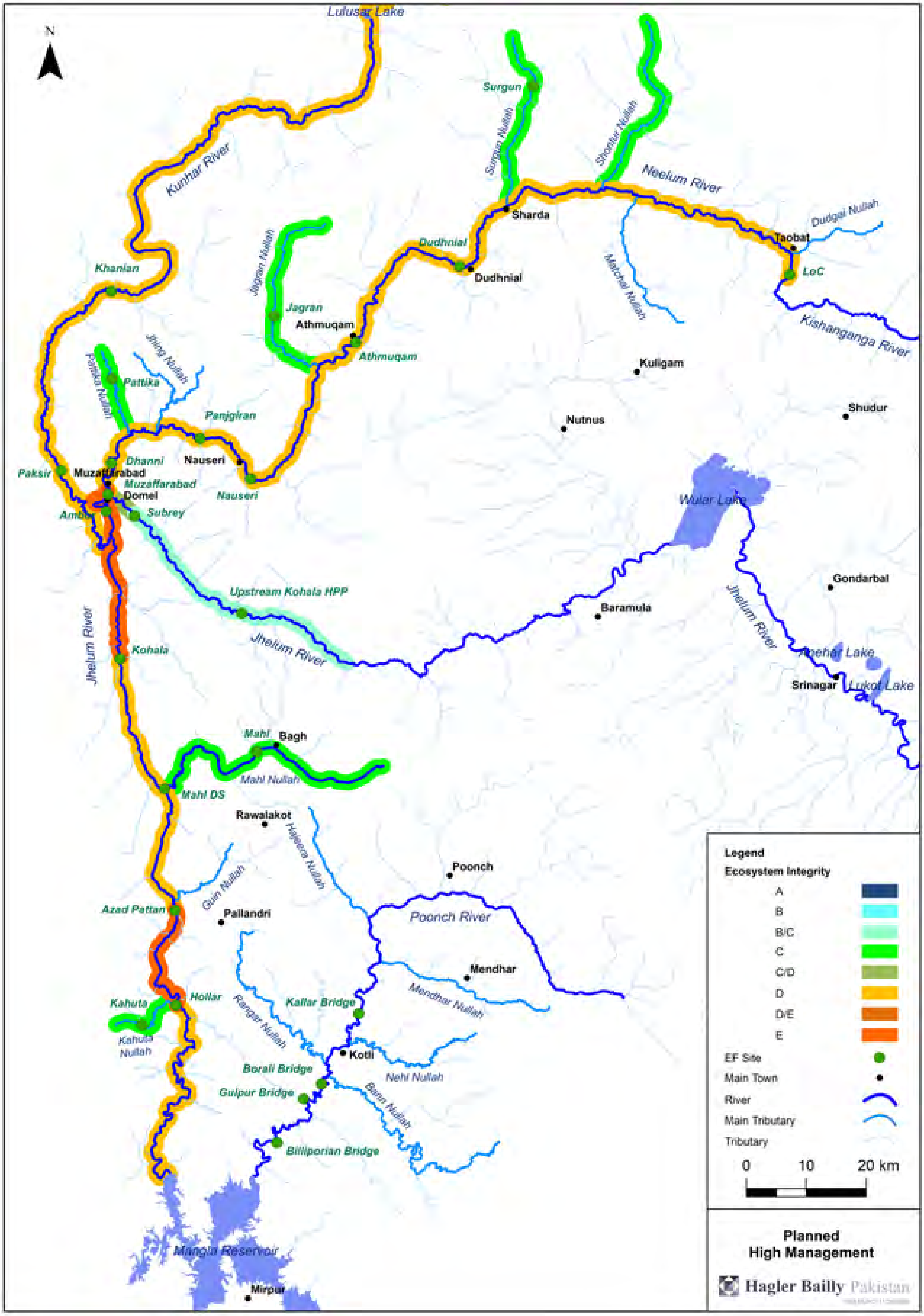


Figure G.A.41: Overall Ecosystem Integrity of the Jhelum-Poonch Basin under Planned: High Management



The fish-integrity results, presented separately in **Table G.A.14**, show several interesting effects, such as the impact of upstream HPPs on rivers downstream of other HPPs. For instance, at Hollar in Lower Jhelum River, fish integrity under the agreed-management scenario is an “E” (**Table G.A.14**) even though the agreed management is Protection Level 2 because it is expected that peaking from the Neelum-Jhelum and Kohala HPPs will not be attenuated by the Karot Reservoir, leading to wide flow fluctuations in the downstream river daily. However, under high management, both HPPs will operate as baseload plants and fish integrity at Hollar is expected to improve to a “D” category (**Table G.A.14**). Thus, the efforts of management at the Kishanganga HPP in protecting the downstream river may be contradicted by operation of upstream HPPs. Other knock-on effects are also evident; for example, sediment flushing will negatively affect fish in the mainstem and have a knock-on effect on fish integrity in Kahuta Nullah as some species will migrate from the main river to the nullah.

The results are discussed in terms of the main subbasins, namely:

- The Neelum River upstream of the confluence with the Jhelum River
- The Kunhar River
- The Upper Jhelum River from the Line of Control to the confluence with the Neelum River
- The Lower Jhelum River from the confluence with the Neelum River to the Mangla Reservoir
- The Poonch River

The outcomes of the scenarios and the reasons behind are broadly consistent across the different versions of the DRIFT DSS. Nonetheless, the 2018 version (this version) does return slightly different results from those of the 2016 version. The differences between the two are related to the updates to the DSS as explained in **Section G.A.3** and changes in the geomorphological indicator response curves to incorporate information from the sediment audit (**Section G.A.2**). For the most part, these are also consistent with the previous version. The single exception is the direction of change predicted for cobble and boulder bars. The explanations in the 2016 DRIFT DSS mentions that sand overlies cobbles, meaning when sand is lost from the system, the result—at least in the short-term—would increase the exposure of the cobble bars. This is how the channel will armor: It will first lose sand and gravel to expose cobbles; over time, because the cobbles are trapped in the HPPs, their amount in the system will fall and the cobble bars themselves will also be washed away. However, it is assumed that this eventuality will take longer than the 30 years modelled in the DSS.

The Neelum River

Most of the impacts in the reach occur with the first tranche of development, that is, existing and under-construction HPPs including Kohala and Neelum-Jhelum. Adding the Athmuqam HPP (committed) and Dudhnial HPP (planned) will lead to incremental impacts on key indicators (see **Annex Table G.A.1-2** and **Annex Table G.A.1-3** in **Annex G.A.1**) and a slight decrease in the overall condition of the river downstream of these HPPs (**Table G.A.13**). This is partly because the Athmuqam and Dudhnial HPPs will operate as true run-of-river baseload plants—that is, hourly flow entering the impoundment equals released flow—and have little influence on downstream flows. They will act as barriers to fish migration and sediment, but their influence is expected to be offset by the large tributaries entering the Neelum River upstream and downstream of these two HPPs. The impact of these two reservoirs on fish integrity is, however, illustrated in **Table G.A.14**, which predicts a 0.5 to 1 category drop in fish integrity if these two HPPs are constructed in the middle Neelum River. This is because construction of the Athmuqam HPP and the Dudhnial HPP would progressively reduce the river between the Kohala HPP and the Neelum-Jhelum HPP, block migration of trout, and reduce the ameliorating effects on flow and sediment patterns if the tributaries enter the Jhelum River along this reach.

At the individual indicators, the sediment changes based on sediment audit are greater than previously estimated, which have particularly affected the geomorphological predictions. These are somewhat alleviated with sediment flushing from the Neelum-Jhelum HPP (**Annex Table G.A.1-5** to **Annex Table G.A.1-7**), although the flushing is prejudicial to fish. In essence, the sediment flushing is predicted to replenish the habitats but is also expected to initially smother some habitats and may clog the gills of fish and invertebrates.

The lack of change in overall integrity at Muzaffarabad under high management is mainly because this study made “E” the lowest category, which encompasses an “E” and an “F” category. In fact, the rating moved from an “F” to an “E,” with some positive changes in key indicators as shown in **Table G.A.15**. For the high-management scenario, the most significant positive changes include reduced nutrient concentration and better water quality, which have a knock-on effect on macroinvertebrates and fish.

Table G.A.14: Fish Integrity for Each EFlow Reach of Each Scenario

River	EFlow site/ reach	Baseline integrity (2012)	Baseline (2012) Business As Usual	Existing and under construction				Committed		Planned	
				Management level				Management level		Management level	
				Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Neelum	Line of Control	B	D	D	D	E	E	D	D	D	D
	Surgun Nullah	B	C	B	B	C	B/C	B/C	B/C	B/C	B/C
	Dudhnial	B	D	C	C	E	E	C/D	C	D	D
	Athmuqam	C	D	D	D	E	E	D	D	D/E	D/E
	Jagran Nullah	B	D	C	B	C	C	C	B	C	C
	Nauseri	C	D/E	E	C	E	E	E	C	E	C
	Panjgiran	C	D/E	E	E	E	E	E	E	E	E
	Pattika Nullah	C	E	E	E	E	E	E	E	E	E
	Dhanni	C	E	E	E	E	E	E	E	E	E
	Muzaffarabad	D	E	E	E	E	E	E	E	E	E
Upper Jhelum	Upstream Kohala HPP	C	E	A	A	B	B	A	A	A	A
	Subrey	C	E	D	D	E	E	D	D	D	D
Kunhar	Khanian	C	E	E	C	E	E	E	C/D	E	C/D
	Paksair	C	E	E	C/D	E	E	E	D	E	D
Lower Jhelum	Ambor	D	E	E	E	E	E	E	E	E	E
	Kohala	D	E	E	D	E	E	E	E	E	E
	Mahl Nullah	C	E	E	A	A	A	E	A/B	E	A/B
	Mahl DS	C/D	E	E	D	E	E	E	E	E	E
	Azad Pattan	C	E	E	C/D	E	E	E	D/E	E	D/E
	Kahuta Nullah	C	E	D	B	D	C/D	D	B/C	D	B/C
	Hollar	C	E	E	D	E	E	E	D	E	D
Poonch	Kallar Bridge	D	E/F	C	Not run			C	Not run	D	Not run
	Borali Bridge	D	F	F				F		F	
	Gulpur Bridge	D	F	B				B		B	
	Billiporian Bridge	D	F	A/B				A/B		A	

Note: SF-4 = April sediment flush; SF-8 = August sediment flush.

Table G.A.15: Predicted Percentage Changes in Indicator at Muzaffarabad for Existing and Under-Construction Scenarios

Indicators		Existing and under construction			
		Management level			
		Agreed	High	High, SF-4	High, SF-8
Geomorphology	Sand and gravel bars/areas	-45.6	-46.8	-1.6	-20.3
	Cobble and boulder bars/areas	23.3	24.7	4.0	17.6
	Depth of pools	0.4	-2.7	-33.3	-15.9
	Median bed sediment size (armoring)	56.0	56.1	32.9	36.2
	Area of secondary channels, backwaters	-97.9	-85.8	-40.6	-55.5
Water quality	Conductivity	9.5	6.6	6.6	6.6
	Nutrient concentration	77.1	35.6	35.6	35.6
	Winter water temperature	-20.1	-16.1	-16.1	-16.1
	Summer water temperature	2.0	5.0	5.0	5.0
Algae	% Filamentous taxa	61.3	55.7	53.8	50.1
	Chlorophyll a/Periphyton biomass	23.1	24.5	21.9	18.3
Macroinvertebrates	Ephemeroptera, Plecoptera, Tricoptera (EPT) abundance	-18.3	-5.9	-51.8	-23.7
	EPT diversity	-23.7	-12.4	-12.6	-12.8
	Simuliidae	42.8	37.0	0.8	22.3
Fish	Alwan snow trout	-72.4	-44.0	-70.4	-63.0
	Kashmir hillstream loach	-76.3	-67.9	-75.4	-74.4

The Kunhar River

The results for the Kunhar River follow a similar trajectory to those of the 2016 DSS. They mainly reflect the drop in condition under the business-as-usual scenario and the barrier effects on fish (mainly Alwan snow trout) from the Patrind, Balakot, and Suki Kinari HPPs. The individual indicator results in **Annex G** show slight incremental impacts after adding the Balakot and Suki Kinari HPPs to the impacts of the Patrind HPP. As is the case for the Neelum River, the high-management scenario results in a more favorable overall integrity because of improved protection levels against non-flow-related impacts in the subbasin.

The Upper Jhelum River

The Upper Jhelum River is affected by the Kishanganga and Kohala HPPs in the existing and under-construction scenario. In this scenario, the reaches upstream of Kohala and at Subrey are modeled under Protection Level 3 under agreed management, which prohibits any use of the river resources. This, combined with the enhanced dry-season flows supplied by the Kishanganga HPP, improves the integrity of the river upstream of Kohala HPP. The river downstream of the Kohala HPP, however, is affected by major changes to the minimum dry-season discharge and the onset and duration of the wet and dry seasons.

With the Chakothi-Hattian HPP (modeled as a baseload plant with some sediment flushing) in place, the reaches upstream of Kohala HPP deteriorates slightly mainly because of its barrier effect on fish migration and sediment supply.

The high management without sediment flushing does not yield major changes in the predicted outcomes. Flushing sediment down the Jhelum River, however, is expected to have negative consequences for the ecosystem, primarily fish. This is mainly because when sediments are periodically flushed from the reservoir, periods of low sediment loads could be interspersed with intermittent periods of heavy, possibly anoxic sediments moving downstream—neither phenomenon is natural and together can cause extreme conditions. In whichever way the channel adjustments play out, downstream riverine habitats and biota will be affected, perhaps through lack of oxygen to support life or sediments clogging the gills of macroinvertebrates and fish as well as important habitats including spawning grounds.

The Lower Jhelum River

The existing and under-construction HPPs on the Lower Jhelum River include Kishanganga, Neelum-Jhelum (tailrace outlet), Patrind, Karot, and Kohala (tailrace outlet). For the most part, they reflect the operating rules and protection provisions already discussed and agreed for Kohala (HBP and Southern Waters 2015b). In this scenario, the condition of the downstream reach of the Mahl River is slightly enhanced by its proximity to the Mahl Nullah. The Kohala, downstream Mahl, and Azad Pattan reaches are heavily affected by the fluctuating flows daily in the dry and transitional seasons as a result of peaking-power generation at the Neelum-Jhelum and Kohala HPPs. These effects might extend to the Azad Pattan and Kohala reaches but are not currently captured by the DRIFT DSS. The benefit to all three sites will increase if the Mahl Nullah is modeled at Protection Level 3, particularly given that the resources of the Mahl Nullah are heavily used at under baseline (2012). The impacts for the existing and under-construction scenarios can also be reduced by running the Neelum-Jhelum and Kohala HPPs as baseload plants.

The second scenario, committed HPPs, adds Mahl and Azad Pattan to the hydropower projects in the Lower Jhelum River. Although the two are both modeled as baseload plants, they peak involuntarily as a result of the peaking effects from the Neelum-Jhelum and Kohala HPPs. Fish and sediments in these reaches are also heavily affected by the barrier effect of the weirs associated with the Mahl and Azad Pattan HPPs.

The Poonch River

The Poonch scenarios are unchanged from those presented in 2016 because they already clearly illustrate the expected negative influence of additional HPPs on the protected fish populations in the Poonch River National Park.

The first two scenarios in the Poonch River include only the Gulpur HPP and reflect the operating rules and protection provisions already agreed or implemented for this HPP (HBP 2014). The planned scenario, which includes the Sehra HPP, is expected to lead to a slight decrease in the condition of the Poonch River upstream of the Gulpur HPP. This minor change in overall integrity, however, belies a 1-category change in fish integrity and a reduction of 20 to 30 percent in species such as the Alwan snow trout and Pakistani labeo. Importantly, to meet IFC's Performance Standard 6, the Sehra HPP would be required to demonstrate a net gain in biodiversity, which, based on the results presented here, looks to be highly unlikely.

G.A.7
Summary and Conclusion

This report covers more technical DSS adjustments done to improve data handling in the Jhelum-Poonch Basin-Wide DRIFT DSS, which was created in 2016 using the individual DSSs developed in EFlow studies for the Gulpur, Karot, Kishanganga, Kohala, and Neelum-Jhelum HPPs.

The scenarios presented here illustrate the cumulative impacts associated with progressive development of HPPs on the mainstream rivers of the Jhelum-Poonch Basin and the possibilities for mitigating these impacts through management and operation (peaking versus baseload power production and sediment flushing). They excluded developments on the nullahs as it was not possible to source the hydrological data needed to model these in the time frame required. The scenarios do, however, include management options for the nullah groups.

At the current level of site-specific data and expert consideration given to the response curves in the DSS, it would be unwise to extend its functionality further following this phase. The DSS would benefit from more detailed attention to hydraulics and hydrodynamics as well as a review of the response curves (particularly those for fish) based on monitoring data collected after the commissioning of the Neelum-Jhelum, Patrind, Gulpur, and other planned HPPs.

The summary results of ecosystem and fish integrity presented in the main body of this report tell a forbidding story on biodiversity protection in the Jhelum-Poonch Basin if the full suite of planned HPPs is implemented. More detailed indicator results in **Annex G** show that it will be extremely difficult, if not impossible, to prevent the loss of fish species under the committed and planned scenarios.

The response curves underpinning the DSS are the result of considerable discussion and review of international literature. They represent the best estimate of the relationships driving the system given current knowledge. As they are documented and motivated clearly in the DRIFT DSS, they can be used as a foundation on which to build future work to add knowledge on the river ecosystem of the Jhelum-Poonch Basin. Further tests can be done on relationships deemed most influential or least known, such as fish-migration patterns following the fragmentation of the main stem and subsequent use of the nullahs as well as ecosystem responses to the releases of peaking power.

ANNEX G.A.1: SCENARIO RESULTS: MEAN PERCENTAGE CHANGE[6]

Annex Table G.A.1-1: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for the Line of Control (Neelum)

Indicators		Base-line (2012) BAU	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
			Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-1.9	-45.8	-45.8	0.6	-12.7	-45.8	-45.8	-45.8	-45.8
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-1.3	25.1	25.1	3.7	16.4	25.1	25.1	25.1	25.1
	Area of cobble bars									
	Depth of pools	-1.8	1.9	1.9	-31.3	-5.3	1.9	1.9	1.9	1.9
	Median bed sediment size (armoring)	0.0	33.8	33.8	8.3	10.0	33.8	33.8	33.8	33.8
	Area of secondary channels, backwaters	-2.8	-42.0	-42.0	8.0	-29.5	-42.0	-42.0	-42.0	-42.0
Water quality	Conductivity									
	Nutrient concentration	2.2	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
	Winter water temperature	0.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
	Summer water temperature									
Algae	% Filamentous taxa	0.4	32.3	32.3	30.9	27.2	32.3	32.3	32.3	32.3
	Chlorophyll a/Periphyton biomass	0.2	16.5	16.5	15.7	13.7	16.5	16.5	16.5	16.5
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-30.9	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3
Macroin-vertebrates	Ephemeroptera, Plecoptera, Tricoptera (EPT) abundance	-4.3	-7.8	-7.8	-52.3	-20.5	-7.8	-7.8	-7.8	-7.8
	EPT diversity									
	Caenidae									
	Simuliidae	-2.4	13.4	13.4	-14.4	3.9	13.4	13.4	13.4	13.4
	Physa									
	Other flies and midges	1.9	6.2	6.2	7.3	7.3	6.2	6.2	6.2	6.2
Fish	Brown trout	-25.5	-31.9	-31.9	-59.9	-51.2	-31.9	-31.9	-31.9	-31.9
	Alwan snow trout	-25.0	-26.2	-26.0	-58.2	-48.8	-28.4	-28.4	-38.5	-38.5
	Chirruh snow trout									
	Tibetan snow trout	-25.2	-23.3	-23.3	-54.4	-49.1	-23.3	-23.3	-23.3	-23.3
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish	-28.3	-8.0	-8.0	-44.0	-43.4	-8.0	-8.0	-8.0	-8.0
	Kashmir catfish									
	High altitude loach	-26.0	-32.3	-32.3	-58.0	-59.4	-32.3	-32.3	-32.3	-32.3
	Kashmir hillstream loach	-35.1	-36.8	-36.8	-68.7	-62.0	-36.8	-36.8	-36.8	-36.8
	Nalbant loach									
	Twin-banded loach									

[6] In all the following tables, blue and green are major changes that represent a move toward natural: green = 40–70%; blue = >70%. Orange and red are major changes that represent a move away from natural: orange = 40–70%; red = >70%. Baseline, by definition, equals 100%.

Annex Table G.A.1-2: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Dudhnial (Neelum)

Indicators		Baseline (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	-1.9	-21.6	-21.6	19.2	-8.8	-21.6	-21.6	-51.0	-51.0
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-1.3	13.0	13.0	-16.8	5.2	13.0	13.0	27.5	27.5
	Area of cobble bars									
	Depth of pools	-1.6	2.7	2.7	-28.6	-4.0	2.7	2.7	8.4	8.4
	Median bed sediment size (armoring)	0.0	13.5	13.5	-6.6	3.0	13.5	13.5	47.1	47.1
	Area of secondary channels, backwaters	-2.8	-29.5	-29.5	14.4	-9.9	-29.5	-29.5	-71.8	-71.8
Water quality	Conductivity									
	Nutrient concentration	2.2	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	Winter water temperature	0.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
	Summer water temperature									
Algae	% Filamentous taxa	0.2	15.3	15.3	14.6	13.3	15.3	15.3	26.8	26.8
	Chlorophyll a/Periphyton biomass	0.2	6.4	6.4	6.0	5.3	6.4	6.4	13.0	13.0
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-31.3	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5	-14.5
Macroinvertebrates	EPT abundance	-4.4	-7.9	-7.9	-50.1	-21.1	-7.9	-7.9	0.7	0.7
	EPT diversity									
	Caenidae									
	Simuliidae	-2.6	5.4	5.4	-19.3	-4.2	5.4	5.4	12.7	12.7
	Physa									
	Other flies and midges	1.9	6.0	6.0	7.3	6.6	6.0	6.0	4.6	4.6
Fish	Brown trout	-24.8	-17.8	-17.8	-54.1	-47.5	-17.8	-17.8	-20.6	-20.6
	Alwan snow trout	-25.2	-12.3	-11.5	-50.8	-41.9	-24.3	-24.3	-30.4	-30.4
	Chirruh snow trout									
	Tibetan snow trout	-25.4	-20.7	-20.7	-54.0	-45.7	-20.7	-20.7	-30.6	-30.6
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish	-28.3	-23.0	-13.1	-48.6	-47.8	-23.0	-13.1	-33.3	-23.5
	Kashmir catfish									
	High altitude loach	-26.0	-21.1	-21.1	-49.5	-54.5	-21.1	-21.1	-31.9	-31.9
	Kashmir hillstream loach	-35.2	-21.4	-21.4	-53.2	-54.9	-21.4	-21.4	-32.1	-32.1
	Nalbant loach									
	Twin-banded loach									

Annex Table G.A.1-3: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Athmuqam (Neelum)

Indicators		Base-line (2012) BAU	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
			Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-1.8	-20.8	-20.8	21.3	-7.5	-48.5	-48.5	-51.0	-51.0
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-1.3	11.2	11.2	-18.5	3.3	26.3	26.3	26.6	26.6
	Area of cobble bars									
	Depth of pools	-1.6	1.9	1.9	-29.6	-5.8	8.1	8.1	8.3	8.3
	Median bed sediment size (armoring)	0.0	11.8	11.8	-8.4	1.4	41.4	41.4	43.9	43.9
	Area of secondary channels, backwaters	-2.8	-26.0	-26.0	18.0	-5.9	-65.3	-65.3	-71.1	-71.1
Water quality	Conductivity									
	Nutrient concentration	3.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	Winter water temperature	0.0	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2	-4.2
	Summer water temperature									
Algae	% Filamentous taxa	0.6	16.0	16.0	15.4	14.3	27.2	27.2	28.2	28.2
	Chlorophyll a/Periphyton biomass	0.4	9.6	9.6	9.0	7.9	20.9	20.9	22.0	22.0
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-36.2	-27.8	-27.8	-27.8	-27.8	-27.8	-27.8	-27.8	-27.8
Macroin-vertebrates	EPT abundance	-14.1	-11.7	-11.7	-52.3	-26.8	-3.3	-3.3	-2.1	-2.1
	EPT diversity									
	Caenidae									
	Simuliidae	10.9	13.9	13.9	-20.3	2.0	20.3	20.3	21.5	21.5
	Physa									
	Other flies and midges	13.2	10.4	10.4	11.7	11.0	9.1	9.1	9.0	9.0
Fish	Brown trout	-12.9	-16.3	-16.3	-53.2	-47.4	-18.4	-18.4	-18.7	-18.7
	Alwan snow trout	-17.7	-14.4	-9.6	-50.0	-42.1	-18.4	-13.7	-31.3	-31.0
	Chirruh snow trout									
	Tibetan snow trout	-15.3	-20.3	-20.3	-44.4	-46.5	-28.7	-28.7	-30.9	-30.9
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish	-25.9	-16.1	-16.1	-50.9	-51.4	-23.2	-23.2	-27.0	-27.0
	Kashmir catfish									
	High altitude loach	-21.0	-21.3	-21.3	-54.0	-49.0	-30.1	-30.1	-32.7	-32.7
	Kashmir hillstream loach	-28.7	-21.4	-21.4	-51.1	-46.5	-30.1	-30.1	-32.8	-32.8
	Nalbant loach									
	Twin-banded loach									

Annex Table G.A.1-4: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Nauseri (Neelum)

Indicators		Baseline (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	-18.2	-16.5	21.9	-15.1	-37.1	-35.5	-47.0	-45.4	-18.2
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-0.2	3.3	-24.2	0.5	18.7	21.0	21.8	23.7	-0.2
	Area of cobble bars									
	Depth of pools	1.0	1.9	-28.3	-1.0	6.6	7.3	7.9	8.6	1.0
	Median bed sediment size (armoring)	13.9	13.9	-5.1	9.8	42.7	42.7	56.3	56.3	13.9
	Area of secondary channels, backwaters	-25.1	-22.6	21.1	-18.7	-48.0	-45.5	-64.8	-62.3	-25.1
Water quality	Conductivity	4.6	4.8	3.1	3.1	3.1	4.8	3.1	4.8	3.1
	Nutrient concentration	5.7	7.8	6.0	6.0	6.0	7.8	6.0	7.8	6.0
	Winter water temperature	0.0	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
	Summer water temperature									
Algae	% Filamentous taxa	1.0	9.3	9.0	8.5	8.0	18.3	17.9	20.8	20.5
	Chlorophyll a/Periphyton biomass	0.6	8.1	7.9	7.3	7.0	17.3	17.1	20.6	20.4
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-22.2	-23.3	0.7	0.7	0.7	-23.3	0.7	-23.3	0.7
Macroinvertebrates	EPT abundance	-15.6	-14.2	-6.1	-43.3	-16.4	-7.4	0.7	-4.1	3.9
	EPT diversity	-6.6	-7.3	-4.6	-4.7	-4.7	-6.7	-4.1	-6.5	-3.9
	Caenidae									
	Simuliidae	11.7	16.9	12.1	-10.7	3.9	20.8	16.1	23.8	19.0
	Physa									
	Other flies and midges	11.1	13.3	4.5	1.0	4.5	14.5	5.7	15.9	7.1
Fish	Brown trout									
	Alwan snow trout	-28.4	-37.6	-7.6	-44.5	-40.0	-36.5	-6.8	-38.8	-9.9
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish	-24.7	-29.7	3.6	-27.6	-35.5	-29.2	4.5	-30.3	4.1
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach	-29.7	-41.3	-6.5	-34.9	-36.4	-42.2	-6.8	-46.9	-12.2
	Nalbant loach									
	Twin-banded loach									

Annex Table G.A.1-5: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Panjgiran (Neelum)

Indicators		Base-line (2012) BAU	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
			Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-4.9	-57.2	-58.5	-11.5	-34.7	-60.9	-62.2	-62.6	-63.9
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-10.6	25.7	27.0	8.4	22.1	26.1	27.3	26.2	27.4
	Area of cobble bars									
	Depth of pools	-2.9	2.2	-0.5	-30.8	-12.6	2.7	0.2	2.9	0.4
	Median bed sediment size (armoring)	0.0	66.3	66.1	42.7	47.1	68.7	68.5	69.7	69.5
	Area of secondary channels, backwaters	-9.1	-96.3	-77.5	-26.8	-48.2	-97.8	-80.8	-98.3	-81.6
Water quality	Conductivity	4.6	10.8	8.0	8.0	8.0	10.8	8.0	10.8	8.0
	Nutrient concentration	6.3	17.2	13.9	13.9	13.9	17.2	13.9	17.2	13.9
	Winter water temperature	-1.0	-21.5	-18.4	-18.4	-18.4	-21.5	-18.4	-21.5	-18.4
	Summer water temperature									
Algae	% Filamentous taxa	1.1	49.3	54.3	52.4	48.3	50.2	55.1	50.5	55.4
	Chlorophyll a/Periphyton biomass	0.7	12.0	26.1	22.9	19.1	13.1	27.1	13.4	27.5
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-24.8	-28.1	-2.2	-2.2	-2.2	-28.1	-2.2	-28.1	-2.2
Macroin-vertebrates	EPT abundance	-12.3	-27.9	-18.6	-54.0	-30.0	-26.8	-17.6	-26.5	-17.3
	EPT diversity	-6.7	-13.7	-10.5	-10.7	-11.0	-13.6	-10.5	-13.6	-10.5
	Caenidae									
	Simuliidae	11.7	27.8	29.5	-4.7	17.9	29.5	31.2	30.1	31.8
	Physa									
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-42.4	-80.0	-52.7	-71.3	-64.7	-79.6	-50.6	-79.4	-49.6
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish	-19.3	-64.6	-36.9	-58.1	-60.5	-64.7	-41.0	-64.7	-41.6
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach	-20.5	-75.8	-58.0	-70.4	-64.7	-75.8	-59.4	-75.8	-59.7
	Nalbant loach									
	Twin-banded loach									

Annex Table G.A.1-6: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Dhanni (Neelum)

Indicators		Baseline (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	-4.9	-49.1	-50.3	-4.8	-23.9	-51.6	-52.8	-52.5	-53.7
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-10.6	23.5	24.9	4.0	17.8	23.9	25.3	23.9	25.3
	Area of cobble bars									
	Depth of pools	-2.9	1.4	-1.6	-32.1	-14.8	2.0	-0.8	2.2	-0.6
	Median bed sediment size (armoring)	0.0	56.6	56.7	34.1	36.8	58.3	58.4	58.7	58.8
	Area of secondary channels, backwaters	-9.1	-97.5	-84.4	-39.6	-53.9	-98.5	-86.4	-98.8	-86.9
Water quality	Conductivity	3.3	9.5	6.6	6.6	6.6	9.5	6.6	9.5	6.6
	Nutrient concentration	6.7	13.5	10.6	10.6	10.6	13.5	10.6	13.5	10.6
	Winter water temperature	0.0	-20.0	-16.3	-16.3	-16.3	-20.0	-16.3	-20.0	-16.3
	Summer water temperature									
Algae	% Filamentous taxa	0.8	36.7	39.7	37.8	34.1	37.6	40.6	37.8	40.8
	Chlorophyll a/Periphyton biomass	1.2	7.2	17.5	14.9	11.3	8.2	18.5	8.4	18.7
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-31.3	-36.0	-2.9	-2.9	-2.9	-36.0	-2.9	-36.0	-2.9
Macroinvertebrates	EPT abundance	-12.3	-18.6	-11.7	-52.6	-28.0	-17.4	-10.6	-17.1	-10.3
	EPT diversity	-6.6	-11.0	-8.1	-8.2	-8.4	-11.0	-8.0	-11.0	-8.0
	Caenidae									
	Simuliidae	11.0	33.9	34.4	-1.8	19.7	35.6	36.1	36.0	36.6
	Physa									
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-40.3	-78.5	-58.0	-72.3	-67.6	-78.4	-56.9	-78.3	-56.5
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach	-45.9	-77.0	-68.5	-73.9	-71.1	-77.0	-68.4	-77.0	-68.4
	Nalbant loach									
	Twin-banded loach									

Annex Table G.A.1-7: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Muzaffarabad (Neelum)

Indicators		Baseline (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	-4.9	-45.6	-46.8	-1.6	-20.3	-47.8	-48.9	-48.5	-49.7
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-10.6	23.3	24.7	4.0	17.6	23.7	25.1	23.8	25.2
	Area of cobble bars									
	Depth of pools	-2.9	0.4	-2.7	-33.3	-15.9	1.0	-2.0	1.2	-1.8
	Median bed sediment size (armoring)	0.0	56.0	56.1	32.9	36.2	57.3	57.5	57.7	57.8
	Area of secondary channels, backwaters	-9.1	-97.9	-85.8	-40.6	-55.5	-98.8	-87.6	-99.0	-88.1
Water quality	Conductivity	3.3	9.5	6.6	6.6	6.6	9.5	6.6	9.5	6.6
	Nutrient concentration	54.3	77.1	35.6	35.6	35.6	77.1	35.6	77.1	35.6
	Winter water temperature	0.0	-20.1	-16.1	-16.1	-16.1	-20.1	-16.1	-20.1	-16.1
	Summer water temperature	0.0	2.0	5.0	5.0	5.0	2.0	5.0	2.0	5.0
Algae	% Filamentous taxa	13.5	61.3	55.7	53.8	50.1	62.1	56.6	62.3	56.8
	Chlorophyll a/Periphyton biomass	13.5	23.1	24.5	21.9	18.3	24.1	25.5	24.3	25.7
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation									
Macroinvertebrates	EPT abundance	-16.6	-18.3	-5.9	-51.8	-23.7	-17.1	-4.7	-16.9	-4.4
	EPT diversity	-13.5	-23.7	-12.4	-12.6	-12.8	-23.6	-12.3	-23.6	-12.3
	Caenidae									
	Simuliidae	17.3	42.8	37.0	0.8	22.3	44.3	38.5	44.7	38.9
	Physa									
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-53.2	-72.4	-44.0	-70.4	-63.0	-72.4	-43.9	-72.4	-44.0
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach	-51.0	-76.3	-67.9	-75.4	-74.4	-75.8	-67.0	-75.6	-66.7
	Nalbant loach									
	Twin-banded loach									

Annex Table G.A.1-8: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Subrey (Upper Jhelum)

Indicators		Baseline (2012) BAU	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
			Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	-4.9	-41.8	-41.0	-30.6	-22.4	-41.8	-41.0	-45.1	-44.3
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-10.8	15.5	16.3	6.0	5.6	15.5	16.3	14.4	15.3
	Area of cobble bars									
	Depth of pools	-3.0	1.7	1.3	-8.1	-8.5	1.7	1.3	2.1	1.7
	Median bed sediment size (armoring)	0.0	24.6	24.2	15.3	8.1	24.6	24.2	27.6	27.3
	Area of secondary channels, backwaters	-8.4	-60.4	-55.8	-43.0	-31.1	-60.4	-55.8	-65.1	-60.4
Water quality	Conductivity	3.3	4.8	5.2	5.2	5.2	4.8	5.2	4.7	5.1
	Nutrient concentration	52.2	1.4	1.7	1.7	1.7	1.4	1.7	1.5	1.7
	Winter water temperature	0.0	-12.8	-13.6	-13.6	-13.6	-12.8	-13.6	-12.9	-13.6
	Summer water temperature									
Algae	% Filamentous taxa	5.2	17.4	17.8	17.7	17.8	17.4	17.8	17.9	18.4
	Chlorophyll a/Periphyton biomass	8.5	4.3	5.0	4.9	5.0	4.3	5.0	4.4	5.0
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-21.0	-11.5	-11.3	-11.3	-11.3	-11.5	-11.3	-11.7	-11.6
Macroinvertebrates	EPT abundance	-11.4	-19.9	-18.7	-44.7	-39.2	-19.9	-18.7	-19.4	-18.2
	EPT diversity	-12.1	-5.1	-5.2	-5.2	-5.2	-5.1	-5.2	-5.1	-5.2
	Caenidae	-25.0	-3.1	-2.6	-0.1	2.1	-3.1	-2.6	-4.1	-3.6
	Simuliidae	20.0	18.0	18.2	-7.0	-0.6	18.0	18.2	19.0	19.2
	Physa									
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-76.5	-27.5	-19.6	-40.5	-42.6	-27.5	-19.7	-28.7	-20.9
	Chirruh snow trout	-75.4	-11.4	-4.1	-14.3	-15.7	-11.4	-4.1	-14.2	-6.6
	Tibetan snow trout									
	Indus garua	-42.0	7.9	8.0	-33.8	-19.6	7.8	7.8	7.4	7.4
	Gora chela									
	Mahseer									
	Pakistani labeo	-59.8	-52.9	-40.0	-63.2	-65.8	-52.9	-43.1	-52.4	-42.6
	Suckerhead	-47.9	34.5	34.8	27.5	28.4	34.4	34.7	34.1	34.3
	Himalayan catfish									
	Kashmir catfish	-34.0	-59.9	-52.5	-86.3	-81.2	-59.9	-52.5	-58.1	-50.6
	High altitude loach									
	Kashmir hillstream loach									
	Nalbant loach	-33.9	-4.7	-4.7	-24.0	-19.3	-4.7	-4.7	-4.9	-4.9
	Twin-banded loach									

Annex Table G.A.1-9: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Upstream Kohala HPP's (Upper Jhelum)

Indicators		Base-line (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-4.9	-18.0	-14.3	-6.4	-3.2	-18.0	-14.3	-33.4	-29.8
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-10.2	8.0	12.7	3.2	1.3	8.0	12.7	12.1	16.2
	Area of cobble bars									
	Depth of pools	-3.0	8.2	8.2	2.2	1.8	8.2	8.2	11.5	11.5
	Median bed sediment size (armoring)	0.0	17.7	17.8	12.3	8.5	17.7	17.8	32.2	32.3
	Area of secondary channels, backwaters	-8.4	-11.7	-11.6	-2.9	3.3	-11.7	-11.6	-26.1	-26.0
Water quality	Conductivity	3.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
	Nutrient concentration	52.2	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.0	-4.0
	Winter water temperature	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.2
	Summer water temperature									
Algae	% Filamentous taxa	0.0	-1.3	-1.4	-1.5	-1.4	-1.3	-1.4	-1.1	-1.1
	Chlorophyll a/Periphyton biomass	7.6	-0.8	-0.8	-0.9	-0.8	-0.8	-0.8	-0.7	-0.7
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-21.0	2.5	2.5	2.5	2.5	2.5	2.5	2.1	2.1
Macroin-vertebrates	EPT abundance	-11.4	3.4	2.5	-29.8	-21.5	3.4	2.5	8.2	7.3
	EPT diversity	-11.2	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1
	Caenidae	-25.1	0.2	0.2	-5.0	-1.1	0.2	0.2	-5.0	-4.9
	Simuliidae	20.0	6.6	6.6	-17.4	-10.9	6.6	6.6	10.4	10.4
	Physa									
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-56.8	18.9	18.9	17.3	18.1	18.9	18.9	-3.3	-3.2
	Chirruh snow trout	-65.2	44.2	44.2	39.7	41.7	44.2	44.2	16.7	16.7
	Tibetan snow trout									
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo	-51.7	15.8	16.0	-10.1	2.0	15.8	16.0	-1.6	-1.4
	Suckerhead	-44.6	43.8	43.8	39.8	39.4	43.8	43.8	34.4	34.4
	Himalayan catfish									
	Kashmir catfish	-33.9	54.0	53.3	-9.0	-33.6	54.0	53.3	56.7	56.0
	High altitude loach									
	Kashmir hillstream loach									
	Nalbant loach	-33.9	22.0	21.9	6.1	8.1	22.0	21.9	23.7	23.7
	Twin-banded loach									

Annex Table G.A.1-10: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Ambor (Lower Jhelum)

Indicators		Baseline (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	0.0	-38.4	-40.3	-11.7	-5.4	-39.9	-41.8	-40.5	-42.5
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	0.0	27.6	27.4	14.1	17.3	27.9	27.8	28.0	27.9
	Area of cobble bars									
	Depth of pools	0.0	1.4	-1.5	-23.2	-17.8	1.8	-1.1	1.3	-1.1
	Median bed sediment size (armoring)	0.0	49.5	48.7	31.3	24.5	50.8	50.1	51.3	50.3
	Area of secondary channels, backwaters	0.0	-83.5	-73.3	-41.1	-25.3	-85.3	-76.3	-86.0	-77.1
Water quality	Conductivity	3.3	6.6	5.9	5.9	5.9	6.6	5.9	6.4	5.8
	Nutrient concentration	52.2	2.4	2.3	2.3	2.3	2.4	2.3	2.2	2.3
	Winter water temperature	0.0	-15.5	-15.3	-15.3	-15.3	-15.5	-15.3	-15.2	-15.4
	Summer water temperature	0.0	5.1	7.0	7.0	7.0	5.1	7.0	5.2	7.2
Algae	% Filamentous taxa	37.4	49.0	44.0	45.1	38.1	49.8	39.7	50.1	37.4
	Chlorophyll a/Periphyton biomass	38.9	50.4	44.8	46.0	39.8	51.2	41.5	51.5	38.9
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-23.0	-15.4	-15.9	-15.9	-15.9	-15.4	-15.9	-16.0	-16.1
Macroinvertebrates	EPT abundance	-13.1	-29.2	-31.0	-55.7	-39.5	-28.6	-30.5	-29.5	-30.7
	EPT diversity	-12.6	-3.7	-4.6	-5.1	-5.0	-3.6	-4.5	-3.7	-4.5
	Caenidae	-24.7	-4.5	-3.0	-4.7	0.4	-6.5	-5.0	-7.0	-5.7
	Simuliidae	21.4	17.8	20.4	-11.9	11.5	18.5	21.1	18.8	21.4
	Physa									
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-61.7	-42.6	-23.9	-80.2	-68.5	-42.7	-24.6	-43.8	-25.3
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua	-43.7	-11.7	-13.6	-63.1	-51.0	-12.0	-14.5	-13.3	-15.1
	Gora chela									
	Mahseer									
	Pakistani labeo	-61.5	-71.0	-33.5	-82.8	-76.7	-71.2	-46.7	-71.1	-46.6
	Suckerhead	-48.5	17.2	23.3	-23.1	-5.1	16.2	20.4	16.0	20.2
	Himalayan catfish									
	Kashmir catfish	-38.8	-92.4	-80.4	-93.6	-92.1	-92.0	-79.8	-92.0	-80.0
	High altitude loach									
	Kashmir hillstream loach	-37.7	-12.3	-25.6	-67.8	-56.3	-13.3	-27.2	-15.6	-28.5
	Nalbant loach	-29.9	-25.0	-26.4	-59.2	-47.0	-24.8	-26.2	-25.7	-26.8
	Twin-banded loach									

Annex Table G.A.1-11: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Kun-Khanian (Kunhar)

Indicators		Base-line (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-4.9	-45.6	-43.9	-24.8	-20.3	-45.6	-43.9	-47.2	-45.5
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-10.8	19.0	21.1	4.0	9.4	19.0	21.1	20.1	21.9
	Area of cobble bars									
	Depth of pools	-2.9	-0.2	0.6	-14.8	-11.8	-0.2	0.6	0.0	0.9
	Median bed sediment size (armoring)	0.0	37.1	37.1	23.7	20.4	37.1	37.1	39.3	39.3
	Area of secondary channels, backwaters	-8.4	-70.6	-68.6	-43.4	-37.8	-70.6	-68.6	-74.3	-72.5
Water quality	Conductivity	4.9	8.7	6.8	6.8	6.8	8.7	6.8	8.7	6.8
	Nutrient concentration	47.1	52.2	25.4	25.4	25.4	52.2	25.4	52.2	25.4
	Winter water temperature	0.0	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8
	Summer water temperature									
Algae	% Filamentous taxa	8.6	45.0	40.0	36.0	36.8	45.0	40.0	46.7	41.8
	Chlorophyll a/Periphyton biomass	9.6	48.3	41.7	37.5	38.4	48.3	41.7	50.2	43.6
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-31.3	-34.6	3.2	3.2	3.2	-34.6	3.2	-34.6	3.2
Macroin-vertebrates	EPT abundance	-11.1	-20.8	-15.0	-48.5	-31.0	-20.8	-15.0	-19.5	-13.7
	EPT diversity	-11.6	-13.2	-7.3	-7.6	-7.6	-13.2	-7.3	-13.0	-7.2
	Caenidae	-30.2	-38.3	-15.3	-17.4	-14.3	-38.3	-15.3	-40.3	-17.3
	Simuliidae	19.1	36.6	25.5	-4.2	11.6	36.6	25.5	37.9	26.9
	Physa									
	Other flies and midges									
Fish	Brown trout	-23.7	-56.1	-15.0	-65.1	-55.9	-56.1	-15.0	-56.9	-15.9
	Alwan snow trout	-30.0	-55.2	-0.4	-64.4	-52.5	-59.1	-6.6	-58.4	-5.9
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach	-55.5	-80.5	-26.3	-71.9	-60.7	-80.5	-26.3	-81.2	-27.9
	Nalbant loach									
	Twin-banded loach									

Annex Table G.A.1-12: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Kun-Paksair (Kunhar)

Indicators		Baseline (2012) BAU	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
			Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	-4.9	-28.6	-26.9	-12.6	1.2	-43.3	-41.6	-43.4	-41.7
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-10.7	6.8	10.2	-8.9	-5.2	17.1	19.8	17.2	19.8
	Area of cobble bars									
	Depth of pools	-2.9	1.5	2.4	-13.3	-12.0	5.7	6.5	5.7	6.5
	Median bed sediment size (armoring)	0.0	18.4	18.4	6.0	1.2	39.8	39.8	39.9	39.9
	Area of secondary channels, backwaters	-8.4	-38.5	-36.1	-19.8	0.8	-55.9	-53.4	-56.1	-53.7
Water quality	Conductivity	4.9	7.6	5.7	5.7	5.7	7.5	5.7	7.5	5.7
	Nutrient concentration	69.1	72.7	36.8	36.8	36.8	72.6	36.7	72.6	36.7
	Winter water temperature	0.0	-7.4	-7.4	-7.4	-7.4	-7.2	-7.2	-7.2	-7.2
	Summer water temperature									
Algae	% Filamentous taxa	12.7	31.2	24.5	22.5	23.4	38.1	31.4	38.2	31.5
	Chlorophyll a/Periphyton biomass	17.1	39.5	27.6	25.6	26.5	47.1	35.3	47.2	35.4
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-28.8	-30.0	12.8	12.8	12.8	-29.9	12.9	-29.9	12.9
Macroinvertebrates	EPT abundance	-27.5	-18.2	-52.2	-31.6	-23.0	-13.8	-23.0	-13.7	-27.5
	EPT diversity	-17.7	-9.0	-9.2	-9.1	-16.9	-8.4	-16.9	-8.4	-17.7
	Caenidae	-36.8	-13.0	-14.9	-11.8	-43.3	-19.5	-43.4	-19.6	-36.8
	Simuliidae	31.7	18.6	-9.6	5.7	37.9	24.8	38.0	24.9	31.7
	Physa									
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-32.5	-61.2	-21.0	-77.3	-67.1	-65.4	-33.7	-65.4	-33.6
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua									
	Gora chela									
	Mahseer									
	Pakistani labeo									
	Suckerhead									
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach	-57.3	-70.0	-7.0	-70.9	-58.5	-73.7	-11.9	-73.8	-12.0
	Nalbant loach	-15.7	-26.9	-3.9	-52.9	-35.4	-25.2	-2.4	-25.2	-2.3
	Twin-banded loach									

Annex Table G.A.1-13: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Kohala (Lower Jhelum)

Indicators		Base-line (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-6.8	-39.0	-35.6	-4.6	2.9	-40.1	-36.7	-40.5	-37.0
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-13.9	20.4	23.7	8.6	10.7	20.8	24.0	20.9	24.1
	Area of cobble bars									
	Depth of pools	-3.0	12.1	13.5	-6.2	-2.2	12.3	13.8	12.3	13.7
	Median bed sediment size (armoring)	0.0	56.5	56.4	38.5	31.0	57.6	57.6	57.8	57.8
	Area of secondary channels, backwaters	-9.8	-46.4	-42.5	-8.8	9.8	-49.2	-45.2	-50.1	-46.1
Water quality	Conductivity	3.3	3.3	2.0	2.0	2.0	3.3	2.0	3.3	2.0
	Nutrient concentration	52.2	52.2	7.5	7.5	7.5	52.2	7.5	52.2	7.5
	Winter water temperature	0.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0	-7.0
	Summer water temperature	0.0	2.3	3.1	3.1	3.1	2.3	3.1	2.4	3.2
Algae	% Filamentous taxa	8.0	12.9	14.2	8.4	9.4	12.6	14.4	13.1	14.7
	Chlorophyll a/Periphyton biomass	10.3	22.1	17.8	10.9	11.8	22.5	18.1	22.8	18.3
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation	-23.0	-31.6	-3.6	-3.6	-3.6	-32.0	-5.5	-31.9	-5.4
Macroin-vertebrates	EPT abundance	-11.1	-4.8	1.0	-36.4	-12.6	-4.4	1.4	-4.4	1.4
	EPT diversity	-12.4	-10.6	-3.2	-3.6	-3.5	-10.4	-3.1	-10.5	-3.1
	Caenidae	-24.8	-43.0	-20.5	-22.0	-17.5	-44.3	-21.8	-44.6	-22.1
	Simuliidae	21.4	28.7	14.4	-18.0	2.2	29.3	14.9	29.5	15.2
	Physa	11.4	-19.2	-7.4	-7.4	-7.4	-19.7	-12.1	-19.6	-12.0
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-56.1	-90.7	-21.6	-79.8	-69.8	-91.7	-30.3	-91.5	-30.3
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua	-53.3	-52.3	-1.0	-68.0	-54.9	-57.5	-12.7	-57.7	-12.9
	Gora chela									
	Mahseer	-24.5	-63.1	52.6	-73.9	-68.2	-85.9	-24.6	-86.0	-24.9
	Pakistani labeo	-45.8	-83.7	-1.1	-74.1	-68.2	-86.7	-42.8	-86.8	-42.8
	Suckerhead	-52.0	-53.1	15.7	-28.5	-16.0	-62.9	-9.9	-62.8	-10.0
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach									
	Nalbant loach	-35.5	-90.8	-16.3	-60.4	-46.8	-90.9	-24.8	-90.8	-24.2
	Twin-banded loach									

Annex Table G.A.1-14: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Downstream Mahl (Lower Jhelum)

Indicators		Base-line (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-6.8	-35.5	-32.0	-1.5	5.4	-55.4	-51.9	-55.6	-52.1
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-13.9	22.5	23.5	7.5	9.4	28.0	27.3	28.0	27.3
	Area of cobble bars									
	Depth of pools	-3.0	12.2	13.4	-6.7	-2.6	14.5	15.0	14.5	15.0
	Median bed sediment size (armoring)	0.0	50.9	50.9	33.3	25.9	72.5	72.5	72.4	72.5
	Area of secondary channels, backwaters	-9.8	-42.7	-38.8	-5.0	13.4	-58.1	-66.6	-58.4	-67.0
Water quality	Conductivity	3.3	3.1	1.8	1.8	1.8	3.1	1.7	3.1	1.8
	Nutrient concentration	52.2	51.9	7.1	7.1	7.1	51.9	7.1	51.9	7.2
	Winter water temperature	0.0	0.5	0.5	0.5	0.5	0.4	0.5	0.3	0.4
	Summer water temperature	0.0	0.6	1.0	1.0	1.0	0.7	1.0	0.9	1.2
Algae	% Filamentous taxa	8.0	16.4	12.6	7.1	8.1	-16.0	15.7	-15.6	15.9
	Chlorophyll a/Periphyton biomass	10.3	24.0	16.9	10.3	11.2	11.0	21.3	11.1	21.3
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation									
Macroin-vertebrates	EPT abundance	-11.1	-5.9	0.9	-36.2	-12.4	-3.0	4.6	-3.0	4.5
	EPT diversity	-12.4	-10.7	-3.1	-3.5	-3.5	-10.2	-2.8	-10.2	-2.8
	Caenidae	-24.8	-40.4	-18.2	-19.7	-15.3	-57.2	-33.1	-57.2	-33.2
	Simuliidae	21.4	27.1	12.8	-19.3	0.7	32.0	17.7	32.1	17.9
	Physa	11.4	-20.5	-30.3	-30.3	-30.3	-20.5	-30.3	-20.4	-30.3
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-53.7	-92.6	-34.6	-84.3	-78.1	-96.1	-54.9	-96.1	-55.0
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua	-55.8	-54.0	4.8	-66.4	-53.2	-60.7	-16.3	-60.8	-16.4
	Gora chela									
	Mahseer	-27.1	-76.8	21.8	-81.2	-77.0	-93.7	-52.6	-93.7	-53.0
	Pakistani labeo	-42.0	-86.2	-31.7	-80.4	-77.3	-90.5	-59.9	-90.5	-60.1
	Suckerhead	-50.9	-50.6	17.0	-27.7	-14.9	-57.8	11.5	-57.8	11.4
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach									
	Nalbant loach	-35.5	-89.6	-14.6	-58.9	-44.9	-90.8	-20.4	-90.8	-20.7
	Twin-banded loach									

Annex Table G.A.1-15: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Downstream Azad Pattan (Lower Jhelum)

Indicators		Base-line (2012)	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
		BAU	Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomor-phology	Sand and gravel bars/areas	-6.8	-34.3	-30.8	-1.4	5.6	-61.8	-58.3	-61.8	-58.4
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-14.0	19.8	21.1	5.2	6.8	25.5	25.8	25.5	25.8
	Area of cobble bars									
	Depth of pools	-2.9	9.9	11.5	-8.8	-5.1	13.0	13.4	13.0	13.3
	Median bed sediment size (armoring)	0.0	48.4	48.4	31.6	24.0	75.8	75.8	75.8	75.8
	Area of secondary channels, backwaters	-9.8	-41.0	-36.9	-5.4	14.0	-72.0	-73.9	-72.1	-74.1
Water quality	Conductivity	3.3	3.4	2.0	2.0	2.0	3.3	2.0	3.3	2.0
	Nutrient concentration	52.2	52.3	7.5	7.5	7.5	52.2	7.5	52.3	7.6
	Winter water temperature	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
	Summer water temperature	0.0	0.3	0.5	0.5	0.5	0.2	0.5	0.4	0.6
Algae	% Filamentous taxa	8.0	17.1	13.2	7.5	8.5	-14.2	17.5	-13.9	17.6
	Chlorophyll a/Periphyton biomass	10.3	20.3	15.9	9.1	10.0	11.2	21.5	11.3	21.5
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation									
Macroin-vertebrates	EPT abundance	-11.0	-7.3	-0.8	-37.0	-14.9	-2.3	4.8	-2.3	4.5
	EPT diversity	-12.4	-11.3	-3.3	-3.8	-3.7	-10.2	-2.9	-10.2	-3.0
	Caenidae	-24.8	-39.8	-17.4	-19.2	-14.8	-65.1	-41.1	-65.1	-41.1
	Simuliidae	21.5	27.7	13.4	-18.2	0.6	34.8	20.5	34.9	20.6
	Physa	9.5	-16.6	-24.8	-24.8	-24.8	-16.6	-24.8	-16.6	-24.8
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-75.4	-91.3	-42.3	-85.7	-82.9	-94.2	-86.4	-94.2	-86.4
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua	-62.0	-63.9	-1.3	-69.8	-57.7	-76.3	-30.2	-76.4	-30.7
	Gora chela	-16.1	-16.3	4.4	-63.1	-52.6	-16.6	4.9	-16.7	4.3
	Mahseer	-26.6	-80.6	13.7	-78.9	-75.1	-86.8	-7.1	-86.8	-8.5
	Pakistani labeo	-34.0	-91.3	-62.0	-86.7	-85.5	-93.7	-68.8	-93.7	-69.3
	Suckerhead	-50.8	-53.2	8.2	-37.5	-23.8	-64.4	-6.3	-64.3	-6.4
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach									
	Nalbant loach	-35.5	-45.7	2.3	-37.9	-27.8	-91.2	3.8	-91.2	3.8
	Twin-banded loach									

Annex Table G.A.1-16: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for Karot (Lower Jhelum)

Indicators		Baseline (2012) BAU	Existing and under construction				Committed		Planned	
			Management level				Management level		Management level	
			Agreed	High	High, SF-4	High, SF-8	Agreed	High	Agreed	High
Geomorphology	Sand and gravel bars/areas	-5.6	-55.3	-55.3	-23.0	-15.1	-60.4	-60.3	-60.4	-60.4
	Area of silt/mixed deposits									
	Cobble and boulder bars/areas	-12.5	26.7	25.7	16.5	17.4	27.4	26.1	27.4	26.1
	Area of cobble bars									
	Depth of pools	-2.9	13.1	13.0	-3.5	-0.8	14.1	13.2	14.1	13.1
	Median bed sediment size (armoring)	0.0	74.4	74.4	59.0	51.0	75.7	75.8	75.7	75.7
	Area of secondary channels, backwaters	-9.6	-70.1	-70.5	-35.9	-20.1	-70.8	-75.2	-70.9	-75.4
Water quality	Conductivity	3.3	2.0	2.0	2.0	2.0	1.9	2.0	1.9	2.0
	Nutrient concentration	52.2	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	Winter water temperature	0.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	-0.2	-0.1
	Summer water temperature	0.0	0.1	0.2	0.2	0.2	0.0	0.2	0.2	0.4
Algae	% Filamentous taxa	8.0	14.5	17.5	10.1	11.3	-21.0	17.6	-20.7	17.8
	Chlorophyll a/Periphyton biomass	10.3	20.5	22.4	14.1	15.3	3.4	22.7	3.5	22.8
Riparian vegetation	Width of marginal vegetation zone									
	Recruitment of marginal vegetation									
	Natural-flood-terrace vegetation									
Macroinvertebrates	EPT abundance	-11.2	3.5	4.5	-18.3	-3.1	4.1	5.5	4.0	5.4
	EPT diversity	-12.4	-2.8	-2.9	-3.4	-3.3	-2.9	-2.8	-2.9	-2.8
	Caenidae	-24.8	-37.5	-37.4	-36.9	-34.8	-47.8	-45.7	-47.7	-45.6
	Simuliidae	21.5	19.9	19.9	-13.3	6.0	21.2	21.2	21.3	21.3
	Physa	9.5	-24.4	-6.0	-6.0	-6.0	-24.9	-10.3	-24.8	-10.2
	Other flies and midges									
Fish	Brown trout									
	Alwan snow trout	-55.9	-68.7	-59.5	-79.9	-69.6	-74.0	-63.3	-74.0	-63.1
	Chirruh snow trout									
	Tibetan snow trout									
	Indus garua	-50.9	-14.0	-13.3	-65.9	-54.2	-14.3	-13.3	-14.4	-13.4
	Gora chela	-16.1	4.8	5.0	-25.3	-28.7	4.3	5.1	4.2	5.1
	Mahseer	-45.6	-82.7	-28.3	-80.2	-76.3	-96.5	-34.9	-96.5	-36.1
	Pakistani labeo	-22.7	-63.3	-9.1	-75.7	-70.7	-94.6	-15.0	-94.7	-15.9
	Suckerhead	-47.0	1.8	2.6	-38.8	-27.8	-3.9	2.5	-3.9	2.6
	Himalayan catfish									
	Kashmir catfish									
	High altitude loach									
	Kashmir hillstream loach									
	Nalbant loach	-32.5	-13.8	4.5	-33.4	-24.9	-81.7	2.9	-81.6	2.8
	Twin-banded loach									

Annex Table G.A.1-17: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for the Kallar Bridge (Poonch)

Indicators		Baseline (2012) Pro 1	Baseline (2012) Pro 2	Baseline (2012) BAU	Existing and under construction	Committed	Planned
Geomor-phology	Bedload inflows	0.0	0.0	0.0	0.0	0.0	-87.5
	Suspended sediment inflows	0.0	0.0	0.0	0.0	0.0	-44.3
	Suspended sediment load	1.1	1.1	1.1	1.1	1.1	-37.7
	Active channel width	-2.1	-2.2	5.1	-2.2	-2.2	-7.8
	Exposed sand and gravel bars						
	Area of silt/mixed deposits	0.9	2.6	-0.7	2.6	2.6	1.9
	Exposed cobble and boulder bars						
Water quality	Area of cobble bars	-3.9	1.7	-15.8	1.7	1.7	-9.7
	Depth of pools	-1.7	0.3	-5.4	0.3	0.3	-0.9
	Median bed sediment size	-14.7	-8.9	-18.5	-8.9	-8.9	9.0
	Area of secondary channels, backwaters	-6.2	0.9	-7.0	0.9	0.9	-2.4
Algae	Conductivity						
	Nutrient concentration	23.1	9.7	65.8	9.7	9.7	9.7
Riparian vegetation	Water temperature	2.1	2.1	2.1	2.1	2.1	2.1
	% Filamentous taxa						
	Chlorophyll a/Periphyton biomass	6.7	2.8	20.9	2.8	2.8	4.1
Macroin-vertebrates	Width of marginal vegetation zone						
	Recruitment of marginal vegetation						
	Dry bank	-12.9	17.7	-22.3	17.7	17.7	17.7
	EPT abundance	-3.0	-2.7	-2.8	-2.0	-2.0	-2.0
	EPT diversity						
	Caenidae						
Fish	Simuliidae	-2.9	-1.6	-3.1	-1.6	-1.6	1.8
	Physa						
	Other flies and midges						
	Brown trout						
	Alwan snow trout	-27.6	36.3	-36.0	17.7	17.7	-12.0
	Chirruh snow trout						
	Tibetan snow trout						
	Indus garua	-46.1	42.5	-73.2	-4.5	-4.5	-20.5
	Gora chela						
	Mahseer	-41.6	39.5	-65.3	12.4	12.4	-18.1
	Pakistani labeo	-65.2	70.5	-92.1	44.2	44.2	17.0
	Suckerhead						
	Himalayan catfish						
	Kashmir catfish	-11.4	17.9	-37.8	18.6	18.6	17.7
	High altitude loach						
	Kashmir hillstream loach						
	Nalbant loach						
	Twin-banded loach	-15.4	16.2	-37.7	16.7	16.7	19.7

Annex Table G.A.1-18: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for the Borali Bridge (Poonch)

Indicators		Baseline (2012) Pro 1	Baseline (2012) Pro 2	Baseline (2012) BAU	Existing and under construction	Committed	Planned
Geomor-phology	Bedload inflows	0.0	0.0	0.0	-87.5	-87.5	-95.0
	Suspended sediment inflows	0.0	0.0	0.0	-44.3	-44.3	-66.1
	Suspended sediment load	1.2	1.2	1.2	-62.4	-62.4	-77.2
	Active channel width	-2.8	-2.9	4.4	-55.9	-55.9	-56.7
	Exposed sand and gravel bars						
	Area of silt/mixed deposits	0.8	2.5	-0.9	-8.7	-8.7	-14.4
	Exposed cobble and boulder bars						
Water quality	Area of cobble bars	-3.1	2.5	-15.0	-16.0	-16.0	-21.2
	Depth of pools	-1.7	0.3	-5.4	-18.0	-18.0	-17.2
	Median bed sediment size	-15.7	-10.0	-19.5	8.1	8.1	17.3
	Area of secondary channels, backwaters	-8.6	-1.5	-9.3	-39.2	-39.2	-39.7
Algae	Conductivity						
	Nutrient concentration	23.2	9.8	65.9	52.4	52.4	52.4
Riparian vegetation	Water temperature	2.2	2.2	2.2	16.2	16.2	16.2
	% Filamentous taxa						
	Chlorophyll a/Periphyton biomass	6.7	2.8	20.9	25.6	25.6	27.2
Macroin-vertebrates	Width of marginal vegetation zone						
	Recruitment of marginal vegetation						
	Dry bank	-12.9	17.7	-22.3	13.8	13.8	13.8
	EPT abundance	2.6	-6.7	6.3	2.3	2.3	5.3
	EPT diversity						
	Caenidae						
Fish	Simuliidae	-3.1	-1.9	-3.3	-1.5	-1.5	5.4
	Physa						
	Other flies and midges						
	Brown trout						
	Alwan snow trout						
	Chirruh snow trout						
	Tibetan snow trout						
	Indus garua	-58.2	47.4	-83.3	-81.3	-81.3	-79.5
	Gora chela						
	Mahseer	-67.5	74.8	-93.1	-77.1	-77.1	-76.8
	Pakistani labeo	-96.5	93.6	-99.9	7.1	7.1	10.8
	Suckerhead						
	Himalayan catfish						
	Kashmir catfish	-3.2	17.6	-27.1	-80.5	-80.5	-80.2
	High altitude loach						
	Kashmir hillstream loach						
	Nalbant loach						
	Twin-banded loach	-9.7	13.2	-28.5	-80.2	-80.2	-79.6

Annex Table G.A.1-19: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for the Gulpur Bridge (Poonch)

Indicators		Baseline (2012) Pro 1	Baseline (2012) Pro 2	Baseline (2012) BAU	Existing and under construction	Committed	Planned
Geomor-phology	Bedload inflows	0.0	0.0	0.0	-77.5	-77.5	-86.9
	Suspended sediment inflows	0.0	0.0	0.0	-36.4	-36.4	-52.7
	Suspended sediment load	1.1	1.1	1.1	-25.7	-25.7	-38.2
	Active channel width	0.2	0.1	7.4	-3.1	-3.1	-4.0
	Exposed sand and gravel bars						
	Area of silt/mixed deposits	0.8	2.5	-0.8	-1.3	-1.3	-3.3
	Exposed cobble and boulder bars						
Water quality	Area of cobble bars	-3.1	2.5	-15.0	-4.7	-4.7	-6.6
	Depth of pools	-1.7	0.3	-5.4	-0.1	-0.1	-0.9
	Median bed sediment size	-14.7	-8.9	-18.5	-4.5	-4.5	-2.3
	Area of secondary channels, backwaters	-6.2	0.9	-7.0	0.4	0.4	-0.7
Algae	Conductivity						
	Nutrient concentration	23.2	9.9	65.9	9.9	9.9	9.9
Riparian vegetation	Water temperature	2.2	2.2	2.2	-0.2	-0.2	-0.2
	% Filamentous taxa						
	Chlorophyll a/Periphyton biomass	6.7	2.8	20.9	3.2	3.2	3.6
Macroin-vertebrates	Width of marginal vegetation zone						
	Recruitment of marginal vegetation						
	Dry bank	-12.9	17.7	-22.3	18.2	18.2	18.2
	EPT abundance	1.2	-4.4	4.3	-1.5	-1.5	-1.9
	EPT diversity						
	Caenidae						
Fish	Simuliidae	-2.2	-1.0	-3.0	-1.3	-1.3	-1.0
	Physa						
	Other flies and midges						
	Brown trout						
	Alwan snow trout						
	Chirruh snow trout						
	Tibetan snow trout						
	Indus garua	-57.4	48.9	-83.2	0.7	0.7	1.9
	Gora chela						
	Mahseer	-63.3	58.4	-90.6	8.1	8.1	8.6
	Pakistani labeo	-93.2	92.7	-99.7	72.0	72.0	73.8
	Suckerhead						
	Himalayan catfish						
	Kashmir catfish	-3.3	20.7	-28.4	31.8	31.8	31.1
	High altitude loach						
	Kashmir hillstream loach						
	Nalbant loach						
	Twin-banded loach	-9.8	16.8	-30.4	28.4	28.4	28.4

Annex Table G.A.1-20: Mean Percentage Changes in Abundance (Relative to 2012 Baseline) Predicted for the Billiporian Bridge (Poonch)

Indicators		Baseline (2012) Pro 1	Baseline (2012) Pro 2	Baseline (2012) BAU	Existing and under construction	Committed	Planned
Geomor-phology	Bedload inflows	0.0	0.0	0.0	-63.5	-63.5	-71.4
	Suspended sediment inflows	0.0	0.0	0.0	-27.3	-27.3	-39.2
	Suspended sediment load	2.4	2.4	2.4	-32.6	-32.6	-49.4
	Active channel width	-2.8	-2.9	4.4	-5.0	-5.0	-5.6
	Exposed sand and gravel bars						
	Area of silt/mixed deposits	1.3	3.0	-0.3	-2.8	-2.8	-6.6
	Exposed cobble and boulder bars						
Water quality	Area of cobble bars	-3.1	2.5	-15.0	-2.1	-2.1	-3.2
	Depth of pools	-1.8	0.3	-5.5	1.8	1.8	2.3
	Median bed sediment size	-17.3	-11.6	-21.2	-7.9	-7.9	-4.6
	Area of secondary channels, backwaters	-11.7	-4.7	-12.5	-1.0	-1.0	-1.5
Algae	Conductivity						
	Nutrient concentration	22.9	9.5	65.6	9.8	9.8	9.8
Riparian vegetation	Water temperature	2.2	2.2	2.2	-0.2	-0.2	-0.2
	% Filamentous taxa						
	Chlorophyll a/Periphyton biomass	22.5	8.2	74.6	9.9	9.9	12.3
Macroin-vertebrates	Width of marginal vegetation zone						
	Recruitment of marginal vegetation						
	Dry bank	-12.9	17.7	-22.3	18.2	18.2	18.2
	EPT abundance	-1.8	-5.4	-0.8	-3.4	-3.4	-2.8
	EPT diversity						
	Caenidae						
Fish	Simuliidae	-3.6	-2.3	-4.2	-2.6	-2.6	-1.7
	Physa						
	Other flies and midges						
	Brown trout						
	Alwan snow trout						
	Chirruh snow trout						
	Tibetan snow trout						
	Indus garua	-46.2	44.0	-72.5	28.2	28.2	29.3
	Gora chela						
	Mahseer	-56.3	50.6	-84.2	33.4	33.4	34.9
	Pakistani labeo	-77.9	78.0	-97.3	76.5	76.5	78.1
	Suckerhead						
	Himalayan catfish						
	Kashmir catfish	-3.9	21.3	-29.4	29.3	29.3	29.6
	High altitude loach						
	Kashmir hillstream loach						
	Nalbant loach						
	Twin-banded loach	-13.0	15.4	-35.1	24.6	24.6	25.9

Basin-wide reservoirs-cascade modeling aimed to simulate hydrological flow sequences as a result of hydropower project operations in the Jhelum-Poonch Basin. This report provides a summary of the modeling results.

Approach

To cater for the input requirements of DRIFT DSS, a basin-wide reservoirs-operations model was created in the GoldSim® software package. GoldSim® is the premier Monte Carlo simulation software for dynamically modeling complex systems in engineering, science, and business. GoldSim® is particularly suited for mass balances, including water balances. For the current model, it was not necessary to use the Monte Carlo capabilities of GoldSim®.

The simulated flow sequences were analyzed with the DRIFT DSS to produce ecologically relevant flow indicators that serve as driving variables for the biophysical socio-economic response curves forming the core of the DRIFT DSS approach.

Data

The Jhelum-Poonch Basin

As illustrated in **Figure G.B.1**, the Jhelum-Poonch Basin comprises the upper Jhelum River[1] and its tributaries. The basin is divided into the following subbasins:

- **Upper Jhelum Basin**—including the Jhelum River upstream of Wular Lake, which regulates flow and sediment
- **Middle Jhelum Basin**—including the Jhelum River immediately downstream of Wular Lake and upstream of Domel before the confluence of the Neelum and Kunhar tributaries with the Jhelum
- **Lower Jhelum Basin**—downstream of Domel where the Neelum and Kunhar tributaries join the Jhelum River and up to the Mangla Dam
- **Neelum Basin**—including the Neelum River, a large tributary of the Jhelum River, up to its confluence with the main Jhelum River

Figure G.B.1: The Jhelum-Poonch Basin

[1] In Pakistan, the Jhelum River downstream of the Mangla Dam is typically referred to as the lower Jhelum River. However, in India, the lower Jhelum terminology is used for the river section downstream of Baramulla.

- **Kunhar Basin—**including the Kunhar River, a large tributary of the Jhelum River, up to its confluence with the main Jhelum River
- **Poonch Basin—**including the Poonch River upstream of its confluence with the Mangla Reservoir

The Kanshi River catchment, which also drains into the Mangla Reservoir, has been excluded since there are no HPPs planned in this basin. The catchment is already highly degraded and flows are insignificant.

HPP Design Data

The design and operation information of HPPs has been extracted from feasibility studies, ESIAs, and other sources including:

- URS Scott Wilson Limited, UK (Lead Consultant) supported by FHC Consulting Engineers, Lahore, December 2011, *Azad Pattan Hydropower Project Feasibility Study*, for Alamgir Power Private Limited
- Shanghai Investigation, Design & Research Institute Co. Ltd. in association with Associate Consulting Engineers and Mirza Associates Engineering Services, January 2017, *Mahl Hydropower Project Feasibility Report*, for the China Three Gorges International Corp.
- China Water Resources Beifang Investigation, Design and Research Co. Ltd., April 2016, *Revised Technical Report to Updated Feasibility Study*
- Mirza Associates Engineering Services (Pvt.) Ltd. (Lead Consultant), December 2013, *Feasibility Study of Balakot Hydropower Project*, for the Asian Development Bank
- M/S Pakistan Engineering Services (Pvt.) Ltd. Lahore (Lead Consultant) supported by FICHTNER Consulting Engineers Germany, May 2007, *Feasibility Study of Patrind Hydropower Project*, for STAR Hydropower Limited
- Hagler Bailly Pakistan (HBP), 2017, *Environmental and Social Impact Assessment of Kohala Hydropower Project*, Kohala Hydropower Company Limited
- Wetlands International-South Asia, June 2007, *Comprehensive Management Action Plan for Wular Lake, Kashmir, Department of Wildlife Protection Government of Jammu and Kashmir*
- HBP, 2015, *Environmental and Social Impact Assessment for Neelum-Jhelum Hydroelectric Project*, for Pakistan Water and Power Development Authority (WAPDA)
- HBP, 2014, *Environmental and Social Impact Assessment of Gulpur Hydropower Project*, for Mira Power Limited

Hydrological Baseline

The baseline hydrological flow data used for this study is over a 30-year period from 1980 to 2010 available at the location provided in **Table G.B.1** (Mirza Associates Engineering Services 2013; HBP 2014; HBP 2015).

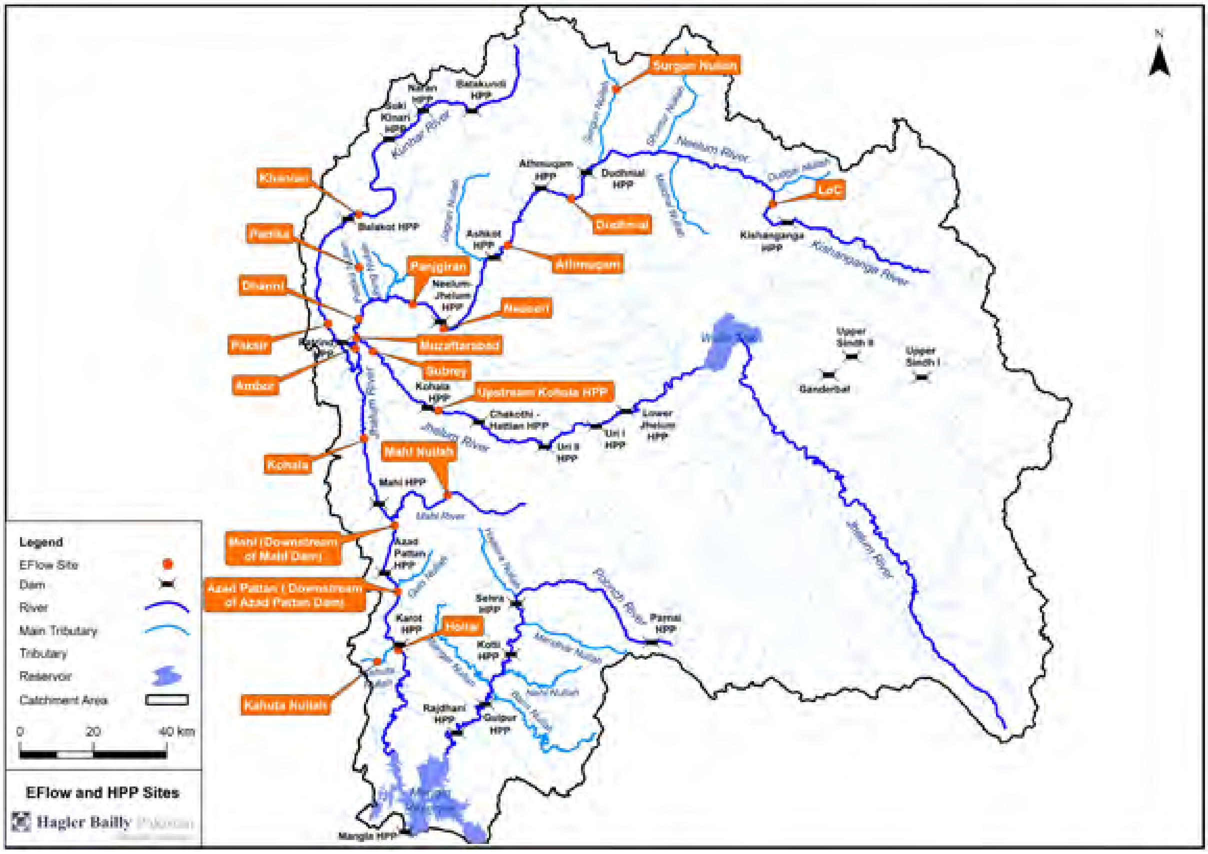
EFlow and HPP Sites

The EFlow and HPP sites in the Jhelum-Poonch Basin are shown in **Figure G.B.2**. The flows at these sites were calculated for the baseline conditions and were then inputted into the GoldSim® model. For this study, the Poonch Basin was excluded from the modeling. The flows for the Poonch Basin as available in the ESIA of the Gulpur Hydropower Project (HBP 2014) were used in the DRIFT DSS. The calculation method for baseline flows at the considered EFlow and HPP sites is described in the following section.

Annex Table G.B.1: Baseline Flow Data in the Basin

Location name	Easting	Northing	Catchment area (square kilometer)	Source of discharge data
Garhi Habibullah	34° 24′ 0″	73° 22′ 48″	2,442	Gauging data
Muzaffarabad	34° 24′ 0″	73° 28′ 48″	7,415	Gauging data
Subrey	34° 21′ 36″	73° 31′ 12″	14,324	Domel gauging data
Ambor	34° 19′ 12″	73° 28′ 12″	21,819	Muzaffarabad and Domel gauging data
Kohala	34° 6′ 36″	73° 30′ 0″	24,874	Kohala gauging data
Hollar	33° 35′ 24″	73° 36′ 36″	26,692	Azad Pattan gauging data
Kotli	33° 29′ 5″	73° 52′ 52″	3,732	Gauging station

Figure G.B.2: EFlow and HPP Sites in the Basin



Baseline Calculations for EFlow Sites and Catchment Contributions

To calculate the 1980–2010 baseline flow at the EFlow sites, the catchment-ratio method was used. A description of the flow determination is provided in **Table G.B.2**. A graph of the daily inflow at the Suki Kinari HPP for a single year is provided in **Figure G.B.3** as an example.

Scenarios and Considerations

Details for different HPPs and management scenarios used in the DRIFT DSS and modeled in GoldSim® for the study are provided in this section.

Several HPPs are in various stages of planning and construction in the Jhelum-Poonch Basin in Pakistan. They were classified into the following three scenarios for the DRIFT DSS:

- *Existing and under construction* (Scenario 1): HPPs that are operational and under construction
- *Committed* (Scenario 2): Upcoming HPPs that are going to be constructed, inclusive of Scenario 1 HPPs
- *Planned* (Scenario 3): Planned HPPs where construction will likely commence within 10 to 20 years, inclusive of Scenario 1 and 2 HPPs

Table G.B.3 shows the HPPs under each scenario.

In addition to the HPP scenarios, two management scenarios were also included for evaluating the operating conditions of different HPPs in the Jhelum-Poonch Basin under the DRIFT DSS. These scenarios include:

- Baseline management
- High management

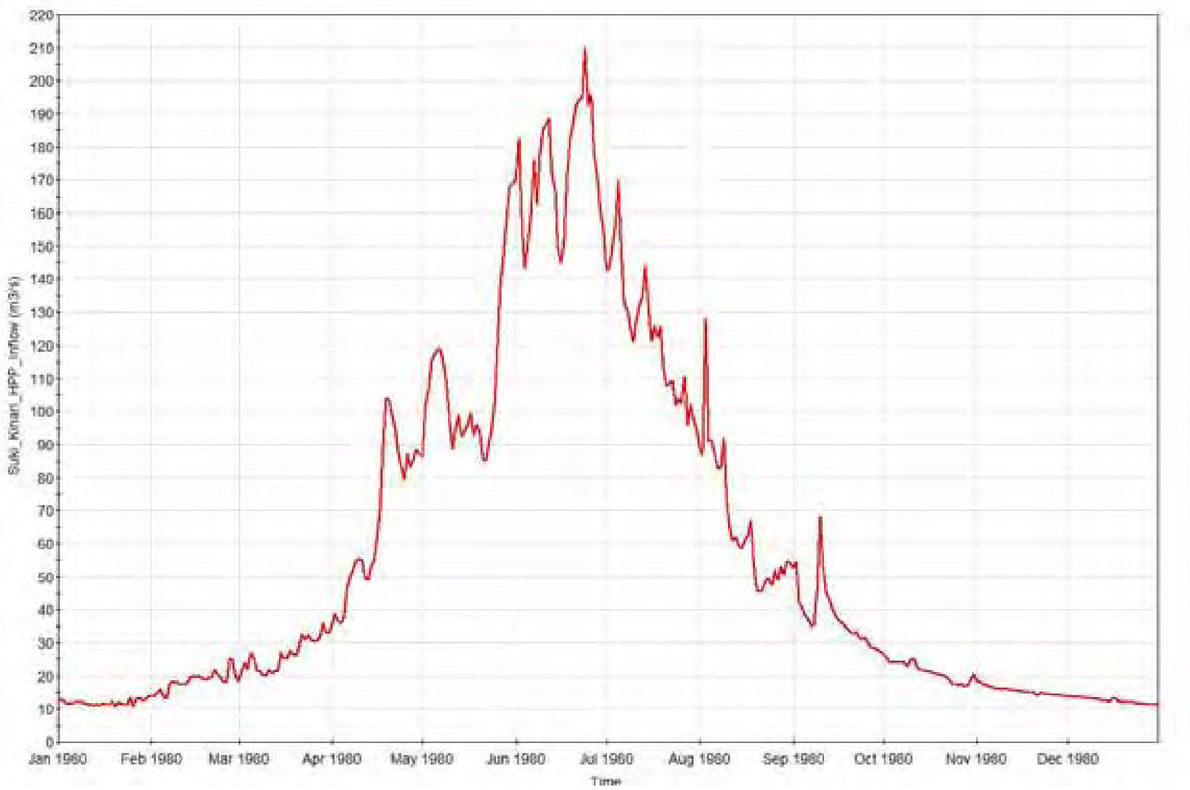
Table G.B.4 provides the details of the operating conditions (peaking vs. baseload operation) of selected HPPs considered for the management scenarios.

Table G.B.5 and **Table G.B.6** shows the environmental flow release and HPP peaking schedule of the projects modeled in GoldSim®, respectively.

Table G.B.2: Calculations Used to Determine Baseline Flows

Location name	Description/remarks
Inflow to the Neelum-Jhelum HPP	The inflow as provided in the ESIA of the Neelum-Jhelum HPP (HBP 2015b) was considered. This included the flow alteration for the Kishanganga HPP as modeled in previous DRIFT assessments.
EFlow sites on the Neelum River	Flows were calculated using the catchment-ratio method on the flow series available at Muzaffarabad.
EFlow sites on the middle Jhelum River (above the confluence of the Neelum and Jhelum rivers)	Flows were calculated using the catchment-ratio method on the flows available at Subrey.
Inflow to the Suki Kinari damsites	Flows were calculated using the catchment-ratio method on the flows available at Garhi Habibullah.
EFlow sites on the Kunhar River	Flows were calculated using the catchment-ratio method on the flows available at Garhi Habibullah.
Inflow to Wular Lake	Using the catchment-ratio method, flows available at Subrey[2] as provided in the ESIA of the Neelum-Jhelum HPP (HBP 2015b) were scaled till Wular Lake, in addition to the flow provided by the Kishanganga HPP diversion (HBP 2011).
EFlow sites on the lower Jhelum (below the confluence of the Jhelum and Kunhar rivers)	Flows were calculated using the catchment-ratio method on the flows available at Kohala and Hollar. For the EF sites downstream of Kohala, flows available at Hollar were used.

Figure G.B.3: Daily Flow Calculated at Suki Kinari (1980)



[2] This flow series considers that the Kishanganga HPP is operating and releasing EFlow at 9 m³/s.

Table G.B.3: HPP Scenarios

Subbasin	HPP	Existing and under construction	Committed	Planned
Neelum	Kishanganga	✓	✓	✓
	Dudhnial			✓
	Ashkot			✓
	Athmuqam		✓	✓
	Neelum-Jhelum	✓	✓	✓
Kunhar	Naran			✓
	Batakundi			✓
	Suki Kinari	✓	✓	✓
	Balakot		✓	✓
	Patrind	✓	✓	✓
Upper Jhelum	Wular			✓
	Lower Jhelum	✓	✓	✓
	Uri I	✓	✓	✓
	Uri II	✓	✓	✓
	Chakothi-Hattan			✓
	Kohala	✓	✓	✓
Lower Jhelum	Mahl		✓	✓
	Azad-Pattan		✓	✓
	Karot	✓	✓	✓
Poonch	Parnai	✓	✓	✓
	Sehra			✓
	Gulpur	✓	✓	✓
	Rajdhani			✓

Note: ✓ - Included

Table G.B.4: Selected HPP Operation

GoldSim® scenario name	Scenario 1	Scenario 1 high	Scenario 2	Scenario 2 high	Scenario 3	Scenario 3 high
Actual scenario name	*Operational and under construction*		*Committed*		*Possible*	
Kishanganga	Peaking	Peaking	Peaking	Peaking	Peaking	Peaking
Dudhnial					Baseload	Baseload
Athmuqam			Baseload	Baseload	Baseload	Baseload
Ashkot					Baseload	Baseload
Neelum-Jhelum	Peaking	Baseload	Peaking	Baseload	Peaking	Baseload
Batakundi					Baseload	Baseload
Naran					Baseload	Baseload
Suki Kinari	Peaking	Peaking	Peaking	Peaking	Peaking	Peaking

GoldSim® scenario name	Scenario 1	Scenario 1 high	Scenario 2	Scenario 2 high	Scenario 3	Scenario 3 high
Actual scenario name	*Operational and under construction*		*Committed*		*Possible*	
Balakot			Peaking	Peaking	Peaking	Peaking
Patrind	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload
Wular					With 2% increase in diversion	With 2% increase in diversion
Lower Jhelum	Peaking	Baseload	Peaking	Baseload	Peaking	Baseload
Uri I	Baseload		Baseload	Baseload	Baseload	Baseload
Uri II	Baseload		Baseload	Baseload	Baseload	Baseload
Chakothi-Hattian					Baseload	Baseload
Kohala	Peaking	Baseload	Peaking	Baseload	Peaking	Baseload
Mahl			Peaking	Baseload	Peaking	Baseload
Azad Pattan			Peaking	Peaking	Peaking	Peaking
Karot	Baseload	Baseload	Baseload	Baseload	Baseload	Baseload

Table G.B.5: Modeled EFlow Release by HPPs

GoldSim® scenario name	Scenario 1	Scenario 1 high	Scenario 2	Scenario 2 high	Scenario 3	Scenario 3 high
HPPs	*Operational and under construction*		*Committed*		*Possible*	
Neelum-Jhelum	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s	9 m^3/s	22.5 m^3/s
Suki Kinari	3.5 m^3/s	3.5 m^3/s	3.5 m^3/s	3.5 m^3/s	3.5 m^3/s	3.5 m^3/s
Balakot			3.5 m^3/s	3.5 m^3/s	3.5 m^3/s	3.5 m^3/s
Patrind	2 m^3/s	2 m^3/s	2 m^3/s	2 m^3/s	2 m^3/s	2 m^3/s
Wular					n.a.	n.a.
Lower Jhelum	8 m^3/s	8 m^3/s	8 m^3/s	8 m^3/s	8 m^3/s	8 m^3/s
Kohala	30 m^3/s	30 m^3/s	30 m^3/s	30 m^3/s	30 m^3/s	30 m^3/s
Mahl			n.a.	n.a.	n.a.	n.a.
Karot	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Table G.B.6: Modeled HPP Peaking Schedule (Where Peaking within a Scenario)

GoldSim® scenario name	Scenario 1	Scenario 1 high	Scenario 2	Scenario 2 high	Scenario 3	Scenario 3 high
HPP	*Operational and under construction*		*Committed*		*Possible*	
Neelum-Jhelum	Month: All Time: 0700–1500	n.a.	Month: All Time: 0700–1500	n.a.	Month: All Time: 0700–1500	n.a.
Suki Kinari	Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200

GoldSim® scenario name	Scenario 1	Scenario 1 high	Scenario 2	Scenario 2 high	Scenario 3	Scenario 3 high
HPP	*Operational and under construction*		*Committed*		*Possible*	
Balakot			Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200	Month: Oct. to Feb. Time: 1700–2200
Patrind	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Wular					n.a.	n.a.
Lower Jhelum	Month: All Time: 0400–2400	n.a.	Month: All Time: 0400–2400	n.a.	Month: All Time: 0400–2400	n.a.
Kohala	Month: Nov. to Jan. Time: 1600–2200	n.a.	Month: Nov. to Jan. Time: 1600–2200	n.a.	Month: Nov. to Jan. Time: 1600–2200	n.a.
Mahl			Month: All Time: 0900–1300	n.a.	Month: All Time: 0900–1300	n.a.
Azad Pattan			n.a.	n.a.	n.a.	n.a.
Karot	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Design Aspects, Considerations, and Recommendations on Optimization

This section discusses the different design aspects and considerations that were taken into account, including those used for developing the management scenarios. The modeled HPPs in GoldSim® are shown in **Table G.B.7**.

Table G.B.7: Projects Modeled in GoldSim®

Basin	Modeled HPPs	Planned operating mode
Kunhar Basin	Suki Kinari HPP	Peaking
	Balakot HPP	Peaking
	Patrind HPP	Baseload
Neelum Basin	Neelum-Jhelum HPP	Peaking
Upper Jhelum Basin	Wular Lake	Diversion scheme
Middle Jhelum Basin	Lower Jhelum HPP	Peaking
	Kohala HPP	Peaking
Lower Jhelum Basin	Mahl HPP	Peaking
	Karot HPP	Baseload

The HPP design information used for modeling was extracted from the sources mentioned in a previous section (**HPP Design Data**). The following provides details on data availability and designs associated with the projects:

- Little information is available on the projects in Indian-administered Kashmir. For this reason, some assumptions were required:
  - Based on current planning, the Government of India plans to install a weir at Wular Lake to increase its water levels for deep infiltration and evaporation. Some additional diversions, such as for agriculture, are expected to be carried out. It was assumed that Wular Lake will have an additional diversion of 2 percent of its inflow for consumptive uses. Better hydrology data and further information is required for the Jhelum Basin in the Indian-administered Kashmir.
  - The Lower Jhelum HPP does not have sufficient live storage to peak effectively. To evaluate peaking potential, a scenario allowing four-hour storage of each data and peaking over a long period on a winter day was considered. Currently, input flow data scaled from gauging stations in Pakistan is used to estimate the inflows for the project. More detail on the exact operating procedure for the Lower Jhelum HPP is needed.
  - Downstream of the Lower Jhelum HPP, Uri I and Uri II have little storage available and will unlikely operate as peaking projects. Nonetheless, these projects will likely rely on any peaking produced upstream at the Lower Jhelum HPP; they were included in the model as elements

(and not reservoirs) to provide the inflows and outflows that would include peaking from the upstream Lower Jhelum HPP.

- The Neelum-Jhelum HPP was part of previously assessed DRIFT scenarios modeled as an all-year-round peaking project for seven hours in the morning with environmental flow release of 9 m^3/s. The peaking model was kept consistent with previous modeling, as this formed a basis for the EFlow assessment for the Neelum-Jhelum project. A baseload-operation model was also constructed in GoldSim® to evaluate management scenarios. The Neelum-Jhelum has a long diversion tunnel with tailrace just upstream of the Mahl HPP reservoir.
- The Kohala HPP was previously modeled as a peaking project of four hours with an EFlow release of 30 m^3/s from November to January for the project's ESIA. Peaking at the Lower Jhelum HPP requires storing water and may reduce inflows to Kohala, making it difficult to maintain both peaking and a consistent EFlow at the project during winter. For the current modeling exercise, the previous Kohala peaking scenario was used, along with development of a baseload-operation scenario. While further assessment of designs will be necessary, Kohala can likely operate in baseload with some power losses in winter.
- The Suki Kinari HPP is designed as a peaking project of five hours from October to February. It was therefore excluded as operating as baseload in the high-management scenario. The Balakot HPP peaks in sync with Suki Kinari as its reservoir is located within 1 km downstream of the Suki Kinari HPP tailrace.
- Originally designed as a peaking project, the Patrind HPP is now planning to operate as baseload and is therefore modeled as one for this study. Nonetheless, given that the upstream Suki Kinari HPP is designed as a peaking project, peaks from Suki Kinari will likely be present at Patrind. The Balakot and Patrind HPPs will synchronize with upstream projects in the cascade and effectively operate as peaking regardless of their own operation mode.
- The Mahl HPP is designed as a power project with year-round peaking. The modeling considered both baseload and peaking scenarios for the project. The Mahl HPP will observe the peaks released from the Neelum-Jhelum HPP and Kohala HPP tailrace in addition to the inflow from upstream. Immediately downstream of the Mahl HPP, the Azad Pattan HPP will also need to operate as a peaking project to synchronize with Mahl peaking.
- Although the Karot HPP was designed as a peaking project, it is planning to operate in baseload and is modeled as one for the study. However, Karot will effectively observe peaks from all upstream HPPs in the cascade and will need to be in sync with them when operating in baseload.

Comparing with the previous modeling exercises for the Kohala ESIA and the EFlow study for the Karot Biodiversity Management Plan, key changes in the current model include:

- Inclusion of baseload and peaking selectors within the GoldSim® model for all modeled hydropower projects
- Using the GoldSim® model, instead of flows from a previous modeling exercise, for the Neelum-Jhelum HPP
- Using the GoldSim® model for Suki Kinari
- Using the GoldSim® model for the Mahl HPP to produce additional peaking through the use of storage at Mahl on top of those reported from the Neelum-Jhelum and Kohala projects at the Mahl Reservoir.
- The Patrind HPP model operating in baseload instead of peaking
- Using the GoldSim® model for the Lower Jhelum HPP to include peaking to the extent possible; this has been under discussion for hydropower projects in Pakistan, particularly since additional flows will be available at the Lower Jhelum project because of the Kishanganga diversion and the possibility that the Lower Jhelum may operate in a peaking mode (with multiple peaks during the day, for example)
- Using the GoldSim® model for Wular Lake to estimate, based on assumptions, consumptive water losses upstream because of government proposals to increase water levels in the lake

Recommendations on Future Modeling for Optimization

Based on the discussions above as well as some limitations of the GoldSim® model that do not consider routing (attenuation), the following are recommended to improve future modeling:

- Additional data for projects in Indian-administered Kashmir and gauging data are needed. The current models use data scaled from gauging stations operating in Azad Jammu and Kashmir, but such scaling has its limitations.
- A power-optimization study is needed for the basin to optimize peaking schedules and power outputs while integrating EFlows and ecological considerations into the schedules. Such an exercise needs to consider the detailed design in terms of whether some projects can be operated in baseload and the impact on power generation. This is particularly important since non-peaking power

projects will still observe peaks from upstream HPPs. It may also be possible to attenuate some of the peaking at the Kohala and Neelum-Jhelum HPPs in the Lower Jhelum Basin, such as at Mahl, Azad Pattan, and Karot through utilization of their storages. An optimization study could consider such aspects to improve ecological conditions downstream of these projects. In addition, scenarios that consider either a ramp up or ramp down to peaking should also be investigated to see if it will improve ecological conditions downstream.

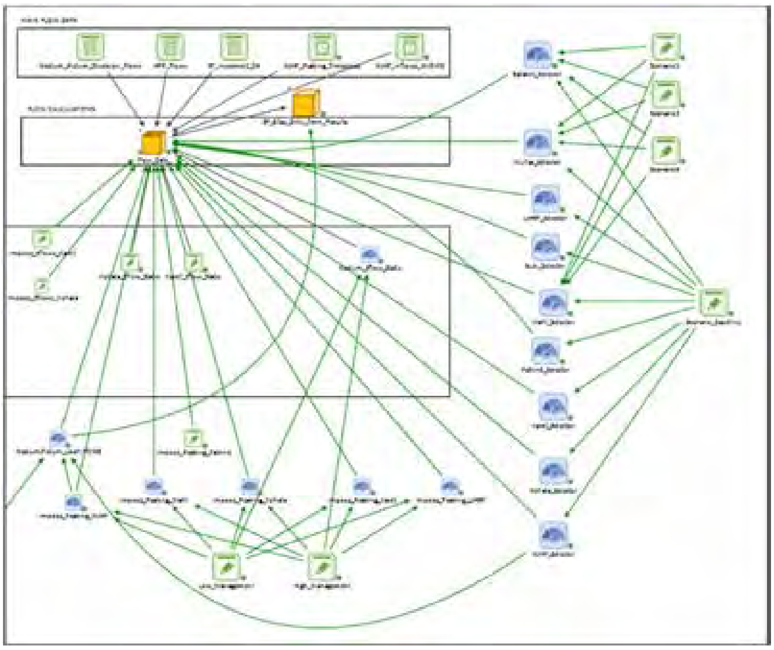
- For a hydropower-optimization study of the scale suggested above, it is necessary to evaluate different optimization models that allow the building of objective functions, including environmental and EFlow considerations as well as sediment modeling. Such an exercise can be carried out in GoldSim®. However, software particularly suited to hydropower optimization will provide additional capability. The Reservoir System Simulation (HEC ResSim) software offers some of these capabilities but needs additional high-quality data to produce better results, such as data on attenuation due to routing.

GoldSim® Model and Setup

Parts of the model setup in GoldSim® for the Jhelum-Poonch Basin is depicted in **Figure G.B.4**. The GoldSim® model computation of the outflows adopts the following calculations:

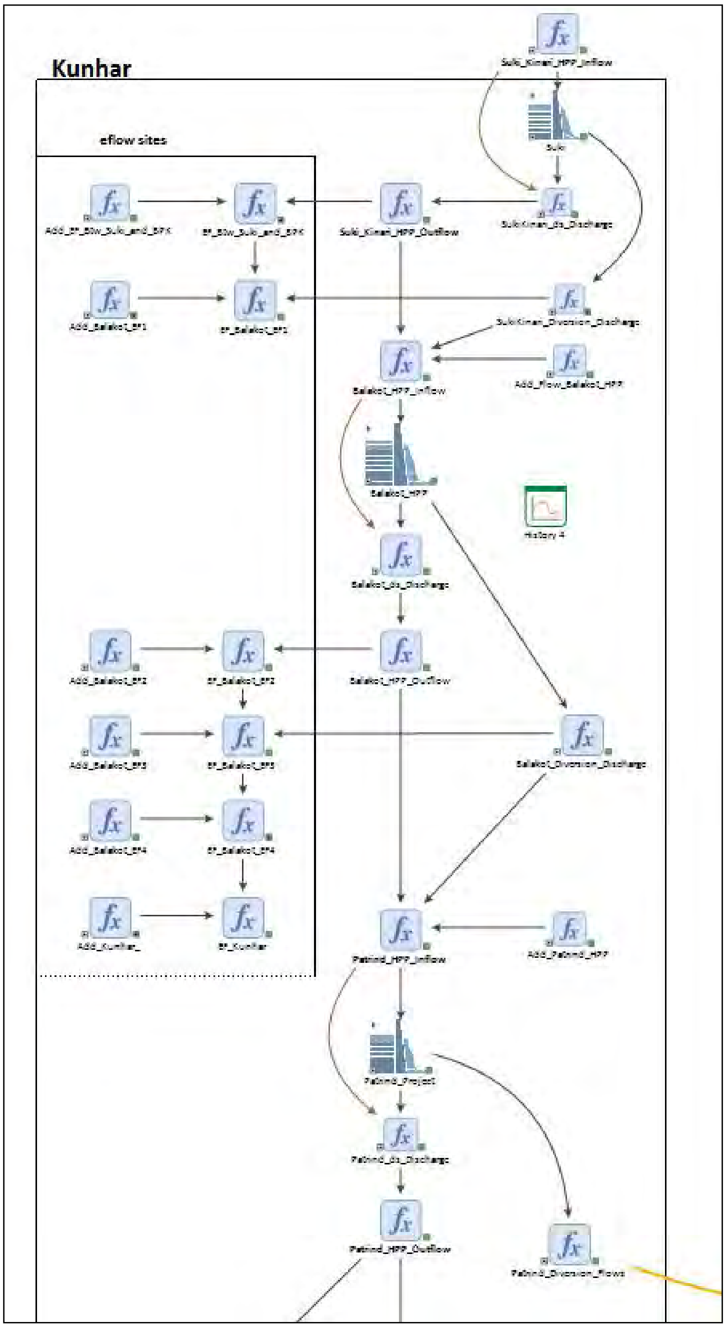
- The model offers what dam operators will experience as close as possible[3] to real-time operation. It is modeled this way so that operating rules, which apply to real-time conditions, can be developed for an environmental flow management plan, which will likely be required by HPPs at a later stage.
- The model uses daily flow and historical-flow data from 1980 to 2010 to project the results for as many situations as possible. The entire hydrological sequence is employed to get an idea of the maximum set of operating conditions.
- The GoldSim® model is run on an hourly timestep. A shorter timestep, such as a minute, for future runs of the GoldSim® model may provide better accuracy in the model outputs, as the outputs are instantaneous flows and peaking is not necessarily carried out at each integer hour. However, since the model is run from 1980 to 2010, a minute timestep will yield over a million timesteps, which cannot be handled easily in GoldSim®. Future updates of the GoldSim® operational model, particularly for DRIFT assessment, should consider decreasing the number of simulation years but change the timestep from hourly to every minute. Separately, an hourly model can be run for computations and evaluations of the range of possible operating conditions or inflows.

Figure G.B.4: Screenshots of Parts of the GoldSim® Model

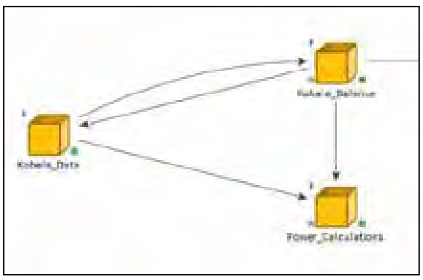


- Main container elements -

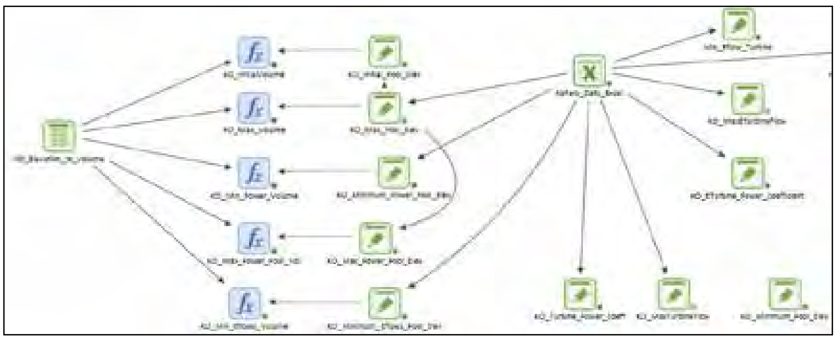
[3] The limitation to achieving true real-time operation is that the flow data is daily while real-time operation will have slightly varying flow over the entire day. Nonetheless, an hourly calculation of water available in storage is carried out.



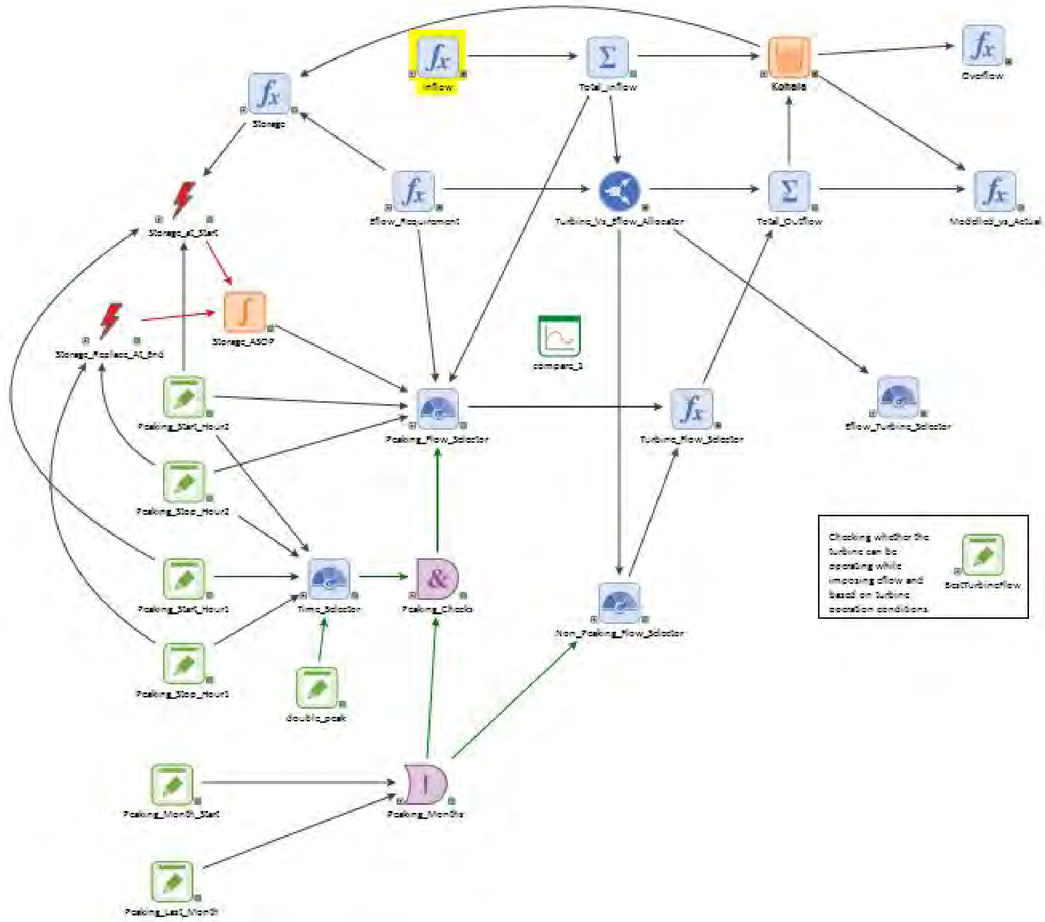
- River schematic (example) -



- Main container -



- Data container -



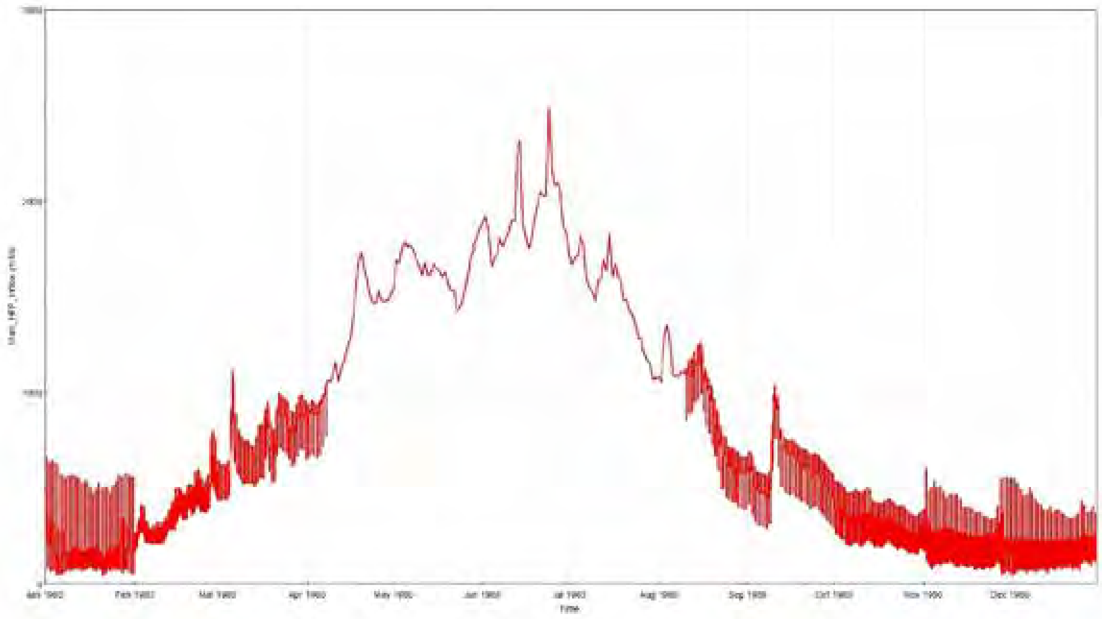
- Kohala model section (example) -

Results

This section provides examples of the simulated scenario results at different EFlow sites. Example graphs of dam outputs (volumes, inflows, and outflows) and flow regimes of the scenarios at designated EFlow sites for the year 1980 are shown in **Figure G.B.5**, **Figure G.B.6**, and **Figure G.B.7**.

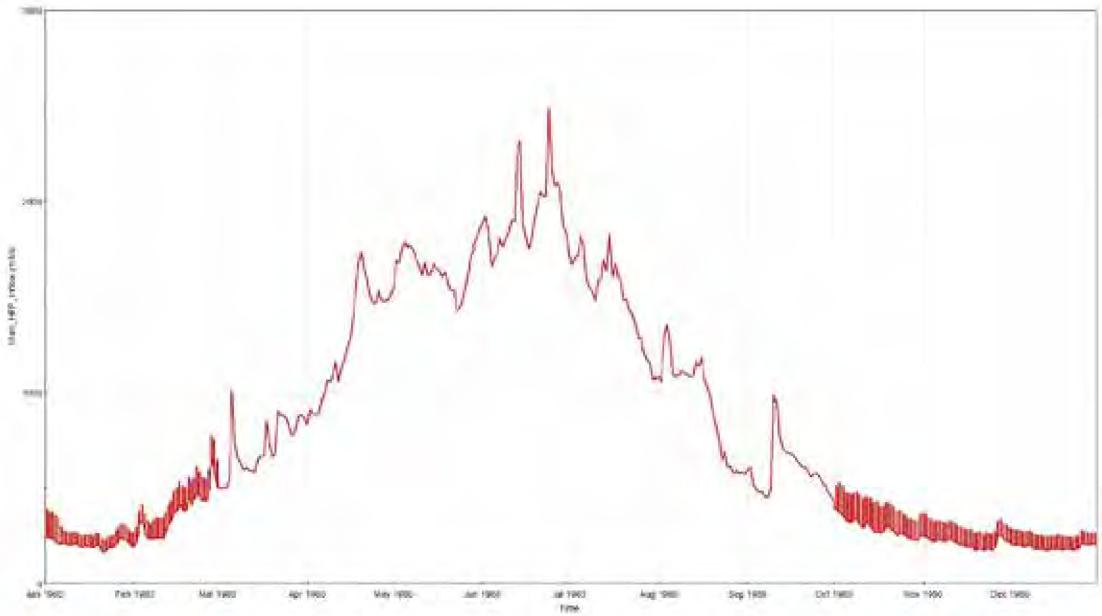
Figure G.B.5: Example of Kohala HPP Dam Outputs for 1980

Figure G.B.6: Example of Mahl HPP Inflow for 1980 under Scenario 3–Baseline Management



The Mahl HPP inflow shows double peaks from the Neelum-Jhelum HPP diversion (morning peak) and evening peaks from the Suki Kinari HPP (coming via the Patrind HPP) and the Kohala diversion. The Neelum-Jhelum HPP peaks all year round, whereas the Suki Kinari and Kohala HPPs peak only in winter. During the flood season, peaking pattern is not observed because of high overflows, although the Neelum-Jhelum HPP still peaks.

Figure G.B.7: Example of Mahl HPP Inflow for 1980 under Scenario 3-High Management



In this scenario, the Neelum-Jhelum and Kohala HPPs are modeled to operate in baseload. The peaks observed at the Mahl HPP inflow are a result of the peaking operation in winter at the Suki Kinari HPP, which passes through the Balakot HPP (which is also peaking) and the Patrind HPP (operating in baseload).

Annex H

Database Framework for Jhelum Poonch Basin

Introduction

This document describes the database framework to aid in creation of the Jhelum database. The key objective of the database will be to provide a unified platform for relevant stakeholders for storage and access of data collected by themselves as well as others, and to facilitate calculation of indicators of change. For hydropower developers in the Jhelum Basin, the database will facilitate collection and analysis of data for monitoring and evaluation as required by the Biodiversity Action and Management Plans prepared for their projects. Additionally, for the proposed Institute for Research on River Ecology (IRRE), where the database is proposed to be housed, the researchers will be able to use the data for assessment of long term trends in degradation or recovery in the river ecosystems, and for the study of linkages between various aspects and parameters that define the ecosystems.

Data Flow and Proposed Responsibilities

Figure H-1 shows the information flow in the Jhelum Basin Database.

Experts associated with the Institute for Research on River Ecology (IRRE), hydropower developers, and monitoring and evaluation consultants engaged by the hydropower developers will be responsible for the input of the data collected and/or obtained. Data updates will be carried out according to the data update frequency requirements specified for the database. Each system user will be provided with a password-controlled customized access to the database which will allow them to interact with the database relevant to their respective roles.

The subject experts at the IRRE will be responsible for verification of data entered by the various system users, including verification of data other users within the IRRE have obtained or gathered. Subject experts can review newly entered data as well as the relevant indicators calculated on the basis of the data. Following a review, the information will be approved for access by the remainder of the users. A yearly review of input data by the IRRE, as well as maximum yearly frequency input of data is proposed.

Where, and if, subject experts find any problems and have some reservation about the data entered, the front-end Graphic User Interphases (GUIs) will allow them to flag the dataset, and or specific values, and provide comments against the flag for the users who entered the data to review. A period of one month will be set for the users to review flagged data, make any amendments in coordination with the subject experts, such that the subject experts can approve the data for sharing with the rest of the users. The reviewed and finalized data will be utilized to develop new indicators. It is proposed that the indicators be shared publicly via the web. The indicators form a subset and summary presentation of the actual data collected and/or gathered.

The data flow diagram (DFD) (**Table H-1**) is proposed for process design as well as to graphically illustrate the sequence of data flows and calculations throughout the system.

There are different front-end modules proposed for entering data attributes, indicators definitions and for setting up a mechanism for calculation of indicators. Basic data can be entered by different users, triggered on the basis of the corresponding system-defined data entry frequency, i.e., (on a weekly, monthly, quarterly or yearly basis).

Specific modules can be set up using SQL (Structured Query Language) to produce output reports specific to the basic requirements for monitoring and evaluation being carried out by the hydropower developers and/or for the hydropower developers by consultants.

The database structure will include two databases:

1. Database housing the main data

2. Database of indicators

A calculator module will allow the extraction of data from the database (SQL) and automatic calculation of various indicators by year.

Indicators

The proposed list of indicators, along with the dataset within the database from which they will be calculated is shown in **Table H-1**.

Descriptions of Data Sets

Table H-2 provides a description of the data that will be included in the database.

Database Structure

The structure for each of the datasets is shown from **Figure H-2** to **Figure H-12**.

Figure H-1: Jhelum Poonch Basin System Data Flow Diagram

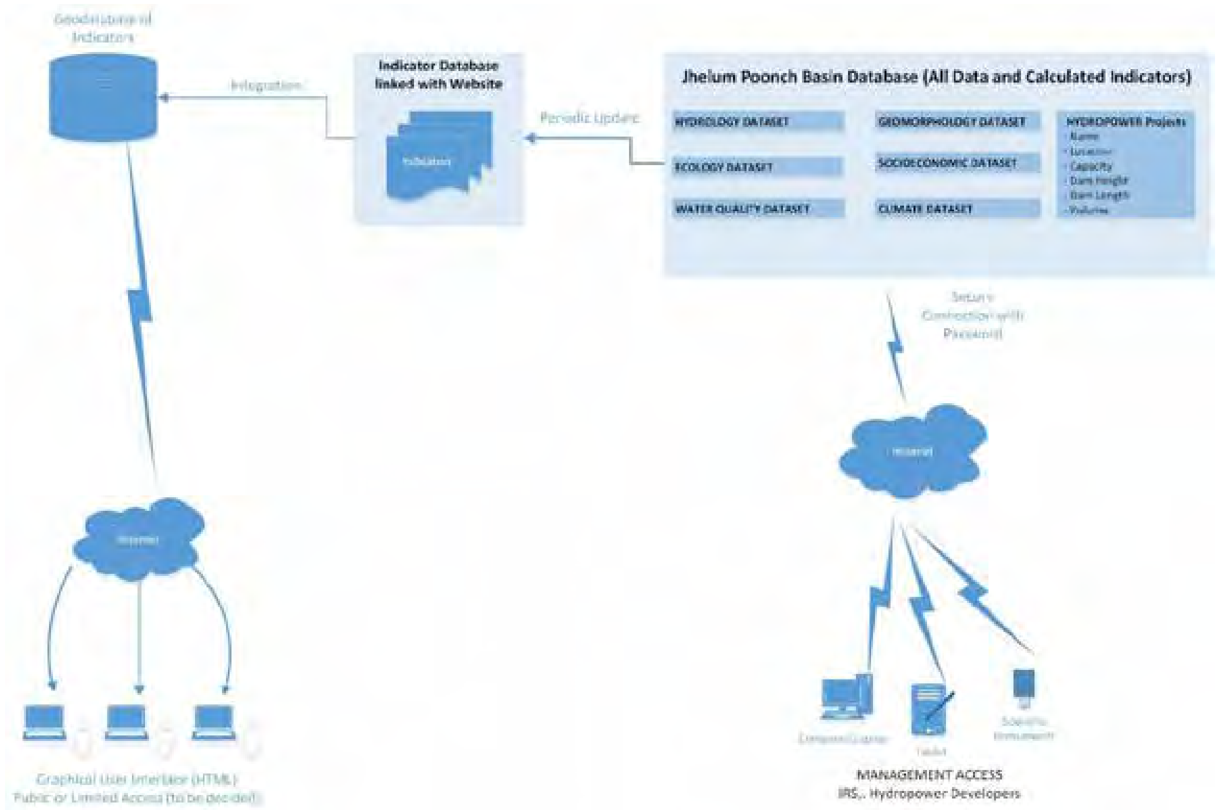


Table H-1: List of Indicators

Phase Code	*Phase*	*Zone*	*Indicator Code*	*Indicator name*	*Indicator Unit*	*Description*	*Data Set Reference*
HYDROLOGY							
TBD	TBD			Mean Annual Runoff	m^3/s	Gives an indication of annual abstraction/addition, and/or annual trends.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Dry season minimum 5-day discharge	m^3/s	Dry season minimum 5-day flows are used as a surrogate for the lowest flows in the concerned area.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Dry season onset	weeks	Start of the winter/Dry flow season.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Dry season duration	weeks	Total length of the winter/Dry season.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Dry season average daily volume	Million cubic meter (MCM)	Average volume of flow received daily in dry season.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Wet season onset	weeks	Start of the summer/ wet flow season.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Wet season duration	weeks	Total length of summer/wet flow season.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Wet season flood volume	MCM	Average volume of flow received daily in wet season.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Within-day range in discharge: Wet, transition and dry seasons	m^3/s	Daily fluctuation of flows from maximum to minimum.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)

Phase Code	Phase	Zone	Indicator Code	Indicator name	Indicator Unit	Description	Data Set Reference
HYDROLOGY							
TBD	TBD			Transition 1 average daily volume	MCM	Average volume of flow received daily during dry to wet season transition period.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Transition 2 average daily volume	MCM	Average volume of flow received daily during wet to dry season transition period.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Transition 2 recession shape	m^3/s/week	Transition 2 recession shape refers to the speed at which the flows change from wet season flows to dry season flows. Under natural conditions this is usually a relatively gentle transition, but this can change with impoundments.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Full time series for entire period of data collection (at multiple locations)	m^3/s	This is required as DRIFT input for future studies. DRIFT includes additional indicators.	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Measured flow data locations	Geographical Coordinates	Locations are required to indicate where the flow data is being collected	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
TBD	TBD			Seasonal flow duration curves	m^3/s against frequency	Flow duration curves to show seasonal variation	Hydrology Dataset (**Table H-2**) and Data Structure (**Figure H-2**)
WATER QUALITY							
Physical Parameters at Hydropower Projects (HPPs) and Gauging Stations							
TBD	TBD		WQP-1.1	Dissolved Oxygen (DO)	mg/l	Amount of gaseous oxygen (O_2) dissolved in the water	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-9**)
TBD	TBD		WQP-1.2	Total Dissolved Solids (TDS)	mg/l	Comprise inorganic salts and organic matter that are dissolved in water	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-9**)
TBD	TBD		WQP-1.3	Monthly Temperature	°C	Variation in daily water temperature over a period of one month	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-9**)
TBD	TBD		WQP-1.4	Minimum Daily Temperature Series	°C	Minimum daily water temperature	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-9**)
TBD	TBD		WQP-1.5	Maximum Daily Temperature Series	°C	Maximum daily water temperature	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-9**)
TBD	TBD		WQP-1.6	Electrical Conductivity	µS/cm	Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-9**)
TBD	TBD		WQP-1.7	pH	log[H]	A numeric scale used to specify the acidity or basicity of an aqueous solution	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-9**)
GEOMORPHOLOGY							
Suspended Solids							
TBD	TBD	TBD	TBD	Active Channel Width	m	The active channel is the width of the bankful discharge channel and is a useful indicator channel capacity/size	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-3**)
TBD	TBD	TBD	TBD	Sediment Concentration	ppm	The ratio of the dry weight of the sediment in a water-sediment mixture (obtained from a stream or other body of water) to the total weight of the mixture.	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-3**)
TBD	TBD	TBD	TBD	Sediment load	Tons/day	Total sediments carried by the water body in form of bed, wash and suspended load	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-3**)

Phase Code	Phase	Zone	Indicator Code	Indicator name	Indicator Unit	Description	Data Set Reference
Others							
TBD	TBD	TBD	TBD	Exposed sand and gravel bars and exposed cobble and boulder bars	%	The availability of exposed bar habitat provides important habitat for vegetation, herpetofauna and birds in the dry season, and fish and invertebrates in the wet season. These bars are also targeted by humans for sediment extraction from the river.	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-4**)
TBD	TBD	TBD	TBD	Depth of Pools	m	The depth of pools indicates the extent of low flow/drought instream habitat refugia.	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-4**)
TBD	TBD	TBD	TBD	Median Bed Sediment Size (armouring)	mm	Average bed material sediment grain size	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-4**)
TBD	TBD	TBD	TBD	Physical barriers	Number / character	Barriers or obstructions to river flow	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-4**)
TBD	TBD	TBD	TBD	Riparian structure or stream bank	% natural, v armored, character	Riparian area is the interface between the land and the river/ stream	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-4**)
TBD	TBD	TBD	TBD	Refugia	Off channel habitat	Amount and character of off-channel habitat available.	Sediment Dataset (**Table H-2**) and Data Structure (**Figure H-4**)
ECOLOGY							
TBD	TBD	All	EFish-1.1	Relative Abundance of Fish	Number	Fish abundance in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-5**)
TBD	TBD	All	EFish-1.2	Fish Species Richness	Number	Total number of species in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-5**)
TBD	TBD	All	EFish-1.3	Endangered (E) and Critically Endangered (CE) Species of Fish	Name of Species	Names of E and CE species in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-5**)
TBD	TBD	All	EFish-1.4	Vulnerable (VU) Species of Fish	Name of Species	Number of VU species in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-5**)
TBD	TBD	All	EFish-1.5	Restricted range/ endemic Species of Fish	Name of Species	Number of restricted range/ endemic species in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-5**)
TBD	TBD	All	EFish-1.6	Migratory Species of Fish	Name of Species	Number of migratory species in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-5**)
TBD	TBD	All	EMac2.1	Abundance of Macro-invertebrates EPT (Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)	Number	Relative abundance of EPT in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-6**)
TBD	TBD	All	EMac2.2	Richness of EPT	Number	Total number of EPT species in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-6**)
TBD	TBD	All	EPer3.1	Periphyton Biomass	g (gram)	Ash Free Dry Weight (AFDW) of Periphyton Biomass in the survey zone.	Ecology Dataset (**Table H-2**) and Data Structure (**Figure H-7**)
SOCIO-ECONOMIC							
Demography							
TBD	All		DEM-1	Demography	Number	Total Number of Households and total population in the Study Area Zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)

Phase Code	Phase	Zone	Indicator Code	Indicator name	Indicator Unit	Description	Data Set Reference
Use of River Resources							
TBD	All		RRE-1	Agricultural land irrigated through river	Kanal	Quantity of Agricultural land irrigated through river water	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-2	Collection of timber or drift wood	Percentage	Households involved in collection of fuel wood from river for house construction, Furniture making and other activities	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-3	Household activities	Number	Total number of households involved in river related activities like washing clothes, walking, swimming, picnics and other river related recreational activities.	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-4	Livestock	Percentage	Percentage of dependence of livestock for drinking purpose on river water	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-5	Riverside hotels and restaurants	Number	Total number of small-scale, mid-scale and large-scale hotels and restaurants in the study area zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-6	Households involvement in riverside hotels and restaurants	Number	Total person involved in small-scale business of hotel/ restaurants in the survey zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-7	Average monthly income / person/ month	PKR	Average earning of a person per month from hotel/restaurants business	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-8	Importance of river for the tourists	Yes/No	Is river important for the tourists in the view of locals	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-9	Trends in riverside recreation	Yes/No	If riverside activities decrease or increase in last 5 years according to the locals	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		RRE-10	Estimate of magnitude of decrease and increase last 5 years	Percentage	In the views of the local communities estimate the change of riverside recreation activities in last 5 years	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
Fishing							
TBD	All		FSH-1	Involvement of people in fishing	Number	Total number of people involved in fishing in the zone (fishermen, processors, retailers)	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-2	Fishing seasons (months)	Number	Number of months people involved in fishing in the zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-3	Fisheries Characteristics	Number	No. of each species caught/fisher type (local sport, commercial, or tourist)/gear/day/zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-4	Fish Catch Characteristics	Kg	Weight of fish caught by species/ gear/zone per month by fisher type.	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-5	Fishing for self-consumption	Percentage	Estimated percentage of fish catch consumed by the household themselves	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-6	Fishing as commercial business	Number	Total number of households involved in fish business in the zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-7	Trends in fishing business	Yes/ No	In the views of the locals fish business increase or decrease in last 5 years	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-8	Magnitude of change in fishing trend	Percentage	According to the locals estimate the percentage change occurs in the fish business in last 5 years	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-9	People directly employed in fishing	Number	Total number of people employed for fishing in the zone (fishermen, processors, retailers)	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-9a	Income from fishing business	PKR/ Month	Average income of fishing business owners	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)

Phase Code	Phase	Zone	Indicator Code	Indicator name	Indicator Unit	Description	Data Set Reference
Fishing							
TBD	All		FSH-9b	Income of people employed in fishing business	Number	Average income of people employed in fishing business	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-10	Angling	Number	Total number of tourists/ locals actively involved in angling in the season in zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		FSH-11	Income from angling	PKR/season	Income generated from each angler, from licenses, guide fees, gear and bait sales	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
Sediment Mining							
TBD	All		SDM-1	Characterization and number of the business	Number	Total number of sand mining business in the study area zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		SDM-2	Characterization of scale of mining business	Percentage	Total number of small-scale, mid-scale and large-scale businesses of sand mining in the survey zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		SDM-3	People involved	Number	Total number of people involved in sand mining in the study area zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		SDM-4	Average monthly income / person/ month	PKR	Average earning of a person per month from sand mining business	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		SDM-5	Quantity of sand mining per person per day	Secra	Secra mined by one person per day	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		SDM-6	Sand / Gravel price	PKR	Price of sand per secra	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		SDM-7	Trends of mining business	Yes/No	If sand mining decrease or increase in the last 5 years according to the locals	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		SDM-8	Magnitude of change in mining trend	percentage	According to the locals estimate the change in sand mining in the last 5 years in the study area zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
Awareness and Protection							
TBD	All		AWP-1	Awareness about national parks or protected areas	Yes/ No	Do local communities know about the national parks or protected areas near the zone, share their views.	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-2	Reasons behind declaring national parks or protected areas	Yes/ No	Do local communities of the zone know the reason behind declaring the national parks or protected areas	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-3	Benefits of national parks or protected areas for local communities	Low, moderate or high (describe benefits)	What are the benefits of national parks or protected areas for local communities/ environment	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-4	Illegal hunting	Number of incidences and methods used	Involvement of locals in illegal hunting in zone and methods used.	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-5	Illegal Fishing	Number of incidences and methods used	Involvement of locals in illegal fishing and methods used like gill net, cast net, blasting, electric shock and poison	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-6	Loss of animals	Rank from 1 (low) – 5 (high)	Loss / decrease of certain animals/ wildlife in study area zone in views of locals	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-7	Awareness about protection activities by Wildlife and Fisheries Departments	Number	Total number of people who know about the protection activities	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)

Phase Code	Phase	Zone	Indicator Code	Indicator name	Indicator Unit	Description	Data Set Reference
Awareness and Protection							
TBD	All		AWP-8	Efficiency of protection	Rank 1 to 5	Assessment of level of efficiency of protection in the study area zone in the views of the local communities	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-9	Awareness about protection of trees / forest	percentage	Percentage of local people aware of protection of tress/ forest in the zone	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-10	Trends in forestation	Increase/ Decrease	According to the locals forest decrease or increase in last 5 years	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-11	Magnitude of change in forests	Percentage	According to the locals estimate the percentage change occurs in the forest in last 5 years	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-12	Reasons of forest increase or decrease		Descriptive	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
TBD	All		AWP-13	Effects of forest increase or decrease		Descriptive	Socio-economic Dataset (**Table H-2**) and Data Structure (**Figure H-8**)
Lab and Field Water Analysis							
Physical Parameters							
TBD	TBD		WQP-1.1	Dissolved Oxygen (DO)	mg/l	Amount of gaseous oxygen (O2) dissolved in the water	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQP-1.2	Total Dissolved Solids (TDS)	mg/l	Comprise inorganic salts and organic matter that are dissolved in water	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQP-1.3	Monthly Temperature	°C	Variation in daily water temperature over a period of one month	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQP-1.4	Minimum Daily Temperature Series	°C	Minimum daily water temperature	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQP-1.5	Maximum Daily Temperature Series	°C	Maximum daily water temperature	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQP-1.6	Electrical Conductivity	µS/cm	Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQP-1.7	pH	log[H]	a numeric scale used to specify the acidity or basicity of an aqueous solution	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
Aggregate Organics							
TBD	TBD		WQA-2.1	Biological Oxygen Demand - 5 day (BOD)	mg/l	Amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in water at certain temperature over a specific time period	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQA-2.2	Chemical Oxygen Demand (COD)	mg/l	Indicative measure of the amount of oxygen that can be consumed by reactions in water.	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
Heavy Metals							
TBD	TBD		WQ-H3.1	Cadmium	mg/l	Amount of cadmium in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQ-H3.2	Lead	mg/l	Amount of lead in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQ-H3.3	Mercury	mg/l	Amount of mercury in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQ-H3.4	Zinc	mg/l	Amount of zinc in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)

Phase Code	Phase	Zone	Indicator Code	Indicator name	Indicator Unit	Description	Data Set Reference
Heavy Metals							
TBD	TBD		WQ-H3.5	Iron	mg/l	Amount of iron in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQ-H3.6	Nickel	mg/l	Amount of nickel in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
Major ions							
TBD	TBD		WQM-4.1	Nitrate	mg/l	Amount of nitrate in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
TBD	TBD		WQM-4.2	Phosphate	mg/l	Amount of phosphate in representative water sample in the zone	Water Quality Dataset (**Table H-2**) and Data Structure (**Figure H-10**)
CLIMATE							
TBD	TBD			Rainfall frequency analysis for 24-hr, 36-hr, 48-hr rainfalls (for multiple periods e.g., 10-year periods, or 20-year periods and at different gauging locations)	mm	Daily variation in rainfall from maximum to minimum	Climate Dataset (**Table H-2**) and Data Structure (**Figure H-11**)
TBD	TBD			Monthly precipitation (at climate station locations)	mm	Precipitation is the condensation of atmospheric water vapor that falls under gravity. The main forms of precipitation include drizzle, rain, graupel and hail.	Climate Dataset (**Table H-2**) and Data Structure (**Figure H-11**)
TBD	TBD			Monthly snowfall (at climate station locations)	mm	Precipitation in form of snow that falls under gravity.	Climate Dataset (**Table H-2**) and Data Structure (**Figure H-11**)
TBD	TBD			Sub-daily air temperature series (at climate station locations)	°C	Daily air temperature series per month	Climate Dataset (**Table H-2**) and Data Structure (**Figure H-11**)

Table H-2: Description of Data Sets

No	Data Aspects	Contents
HYDROLOGY Data Set **Source of data: Gauging stations**		
1.	Date	Day, month and year
2.	Time Series	Instantaneous /Average (sub-daily, daily, monthly or yearly)
3.	Gauging Station Location Information	Coordinates, elevations, location (on river or tributary or dam wall, HPP tailrace).
4.	Gauging Station Information	Operator, start of operation, end of operation (if applicable), current date of operation, catchment area
5.	River Information	Flow (m^3/s)
GEOMORPHOLOGY Data Set **Source of data: Gauging stations**		
6.	Date	Day, month and year
7.	Time Series	Instantaneous /Average (sub-daily, daily, monthly or yearly)
8.	Gauging Station Location	Coordinates, elevation, location (on river or tributary or dam wall or HPP tailrace).
9.	Gauging Station Information	Operator, start of operation, end of operation (if applicable), current date of operation, catchment area
10.	Geomorphology (Suspended Sediment) Information	Water temperature, air temperature sediment flux, sediment concentration (percentage of sand, silt and clay), and sediment size distribution.
11.	Geomorphology (others) Information	Depth of water pool, median bed sediment size (armoring), percentage of exposed sand and gravel bars, percentage of exposed cobble and boulder bars
ECOLOGY Data Set **Source of data: Mainly Surveys**		
Fish Data Set **Sources of data: Mainly Surveys**		
12.	Date & Time	Date, time, start and end
13.	Location Information	Coordinates, location, monitoring sites
14.	Weather Conditions	Air temperature, cloud cover, wind speed, Precipitation
15.	River Characteristics	Riparian structure, river/stream bed habitat, depth, temperature, pH, Dissolved Oxygen (DO)
16.	Sampling Method	Cast net, gill net, fyke net, electrofishing
17.	Fish Species	Survey results, Total fish length, weight, sex by species for each sampling gear
18.	Fish Health	Parasitic load, lesions, lost scale, deformities
19.	Fish Reproductive Stage	Immature, developing, maturing, mature, spawning, spent, resting
Macro-Invertebrates Data Set **Sources of data: Mainly surveys**		
20.	Date & Time	Date, time, start and end
21.	Location Information	Coordinates, location, monitoring sites
22.	Weather Conditions	Air temperature, cloud cover, wind speed, precipitation
23.	River Characteristics	Riparian structure, river/stream bed habitat, depth, temperature, pH, DO
24.	Sampling Method	Kick nets for instance
25.	Macro-invertebrates (EPT) Taxa	Number and diversity
Periphyton Data Set **Sources of data: Mainly surveys**		
26.	Date & Time	Date, time, start and end
27.	Location Information	Coordinates, location, monitoring sites
28.	Weather Conditions	Air temperature, Cloud cover, Wind speed, Precipitation
29.	River Characteristics	Riparian structure, river/stream bed habitat, depth, temperature, pH, DO
30.	Scrape Dimensions	Length, width and height of stone (if rectangular stone), circumference of stone (if circular stone)
31.	General Information	Maximum depth of water (cm), Approximate depth of water above rock (cm)

No	Data Aspects	Contents
SOCIO-ECONOMIC Data Set Sources of data: Primary Data		
32.	Date & Time	Date, time, start and end time
33.	Location Information	Coordinates and Settlement
Demography		
34.	Demography	Number of households and population
Use of River Resources		
35.	Agricultural Land	Total number of agriculture land, land irrigated through river water
36.	Domestic use	Amount of water used for drinking, washing
37.	Commercial use	Amount of water used for artisanal and commercial industry
38.	Drift wood	Household involved in collection of drift wood and uses.
39.	Recreational activities	Household involved in river related recreational activities.
40.	Livestock	Percentage of livestock using river water for drinking.
41.	Riverside hotels and restaurants	Households involved in riverside hotels and restaurants and their income.
Fishing		
42.	Involvement of people in fishing	Number of people directly involved in fishing (fishermen, processors, retailers)
43.	Fisheries Characteristics	No. of each species caught/fisher type (local sport, commercial, or tourist)/gear/day/zone
44.	Fish Catch Characteristics	Weight of fish caught by species/gear/zone per month by fisher type.
45.	Fishing for self-consumption	Estimated percentage of households capture and consume fish by themselves
46.	Fishing as commercial business	Total number of households involved in fish business
47.	Trends in fishing business	Fish business increase or decrease in last 5 years
48.	Angling	Number of tourists/ locals involve in the angling
Sediment Mining		
49.	Number of the business	Total number of sand mining business
50.	Characterization of mining business	Number of small-scale, mid-scale and large-scale businesses of sand mining
51.	People involved	Number of people involved in sand mining
52.	Monthly income	Average monthly income / person/ month
53.	Quantity of sand mining	Quantity of sand mined by one person per day
54.	Sand / Gravel price	Price of sand per secra
55.	Trends of mining business	Sand mining decrease or increase in the last 5 years
Awareness and Protection		
56.	Awareness about national parks	Description
57.	Reasons behind declaring national parks or protected areas	Description
58.	Benefits of national parks or protected areas	Description
59.	Illegal hunting	Number of incidences and methods used
60.	Illegal fishing	Number of incidences and methods used
61.	Loss of animals	Loss / decrease of certain animals/ wildlife
62.	Awareness about protection activities by Wildlife and Fisheries Departments	Number of people who know about the protection activities
63.	Efficiency of protection	Percentage
64.	Awareness about protection of trees / forest	Description
65.	Magnitude of change in forests	Percentage

No	Data Aspects	Contents
WATER QUALITY- Lab and Field Water Analysis Data Set **Sources of data: Mainly Surveys**		
66.	Date	Day, month and year
67.	Location Information	Coordinates, location, monitoring sites
68.	Site Information	Depth of water sample location below water level – m, Height of water sampling location above base – m, Maximum height of water column
69.	Sampling area	Sampling area (center only)
70.	Sampling bottle Information for Heavy Metals	green, red, yellow bottles
71.	Water Quality characteristics	Water quality parameters (e.g. pH, DO, water temperature, electrical conductivity, total dissolved solids)
Water Quality Data Set **Sources of data: Measuring Stations**		
72.	Date	Day, month and year
73	Time Series	Instantaneous /Average (sub-daily, daily, monthly or yearly)
74.	Station Location Information	Coordinates, location (on river or tributary or dam wall).
75.	Station Information	Operator, start of operation, end of operation (if applicable), current date of operation
76.	River Information	Water quality parameters (e.g. pH, DO, water temperature, electrical conductivity, total dissolved solids)
CLIMATE Data Set **Sources of data: Met Stations**		
77.	Date	Day, month and year
78.	Time Series	Instantaneous /Average (sub-daily, daily, monthly or yearly)
79.	Gauging Station Location Information	Coordinates, elevation, location
80.	Gauging Station Information	Operator, start of operation, end of operation (if applicable), current date of operation
81.	Information	Air temperature, precipitation/snowfall
HYDROPOWER Data Set **Sources of data: HPP Developers (Structure of database Figure H-12)**		
82.	Location	Coordinates, elevation, river
83.	Hydropower Project	Power capacity, type of operation (e.g., Run-of-River ROR, Storage), purpose of HPP (e.g., irrigation, power), type of HPP (e.g., Diversion), trap efficiency
84.	Construction Information	Start date, duration, end date/expected end date
85.	Dam Features	Height of dam, type of dam, dimensions, tailrace and headrace length, EFlow released or planned, low level outlets (no. and capacity), gates (no. and capacity)
86.	Reservoir Information	Stage storage, Full Reservoir Level (FRL), Normal Operating Level (NOL), catchment area at FRL
87.	Powerhouse	Main power house turbine (Rated power, No. type and size) EFlow turbine (Rated power, No. type and size)
88.	Flushing Information	Mechanism, schedule

Figure H-2: Data Structure for Hydrology

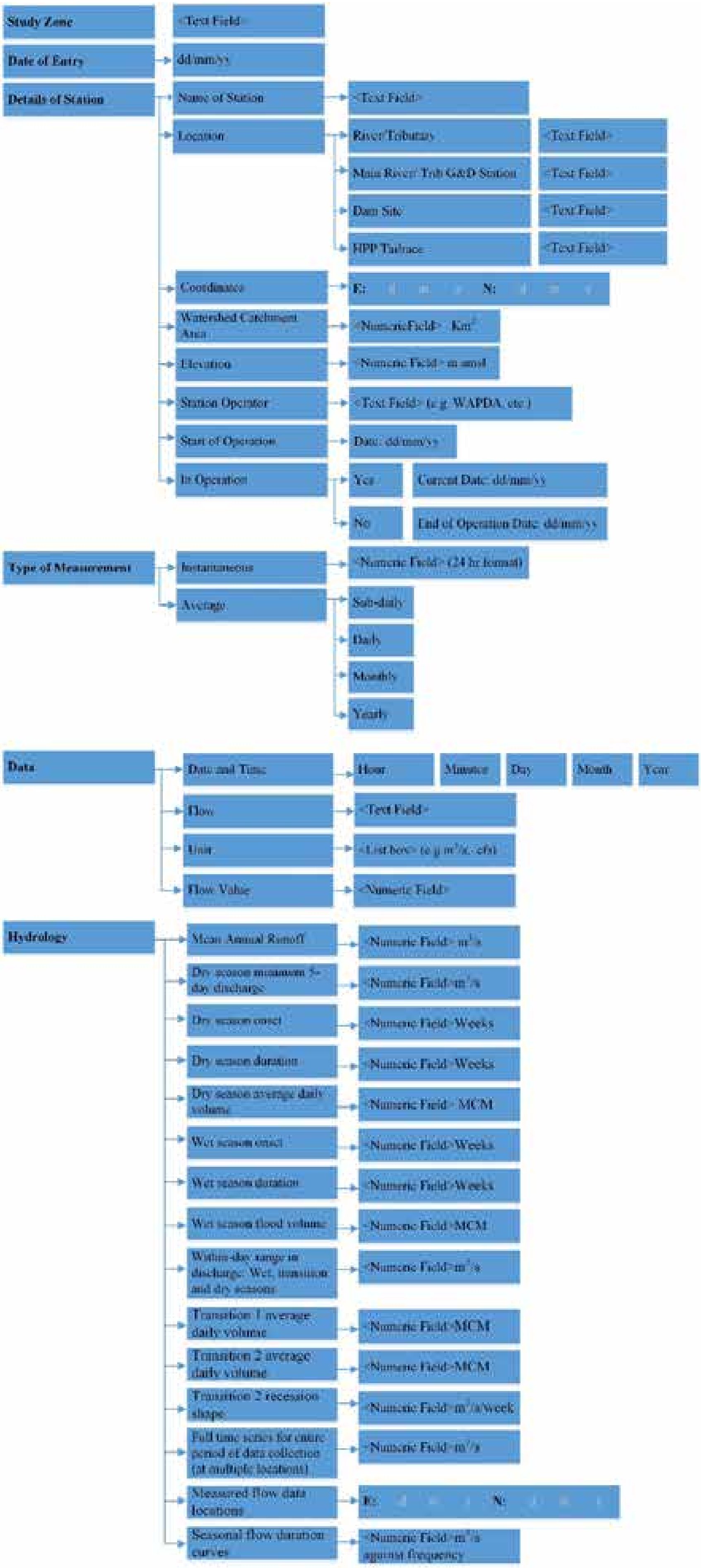


Figure H-3: Data Structure for Geomorphology-Suspended Solid

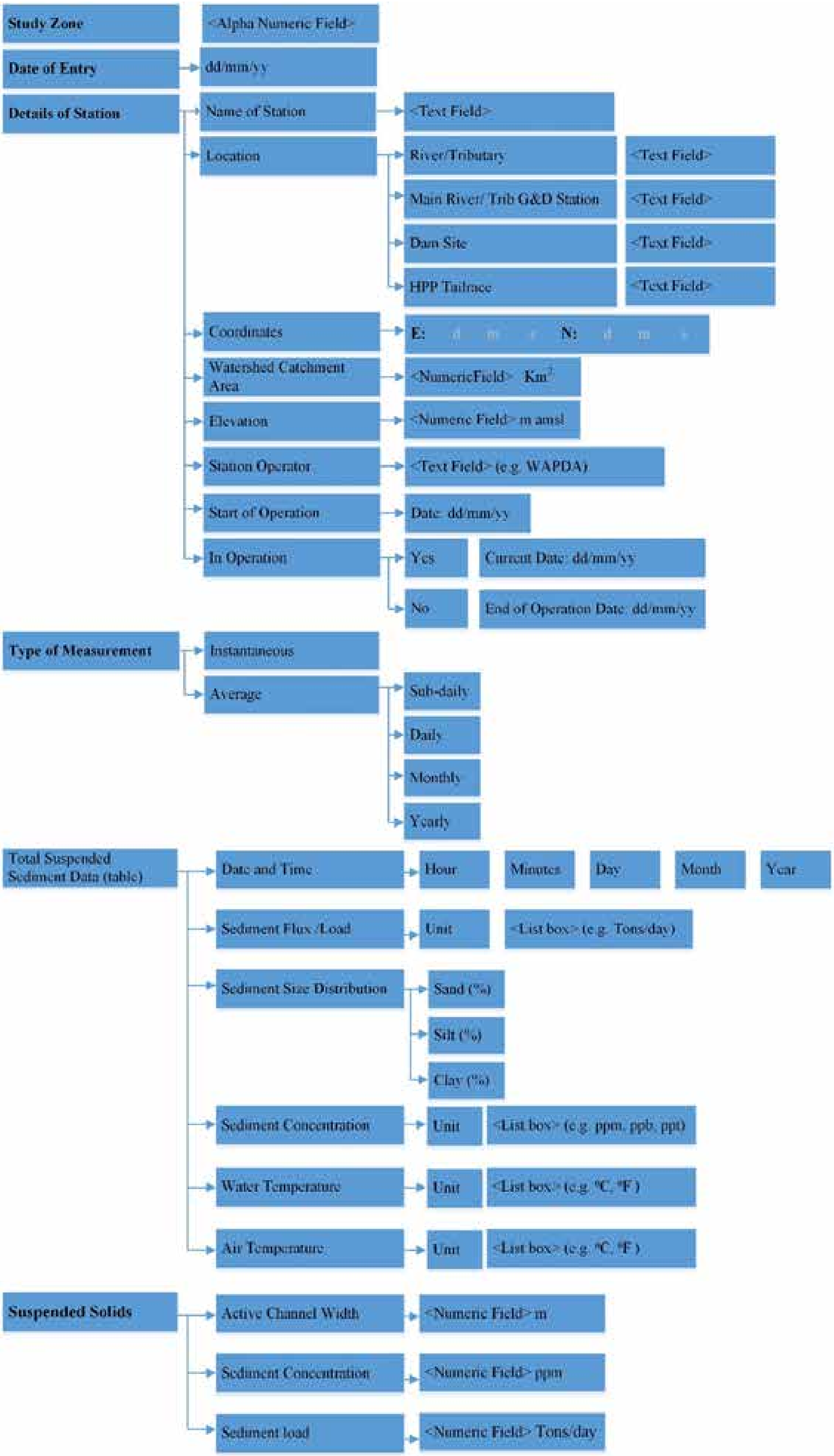


Figure H-4: Data Structure for Geomorphology - Other

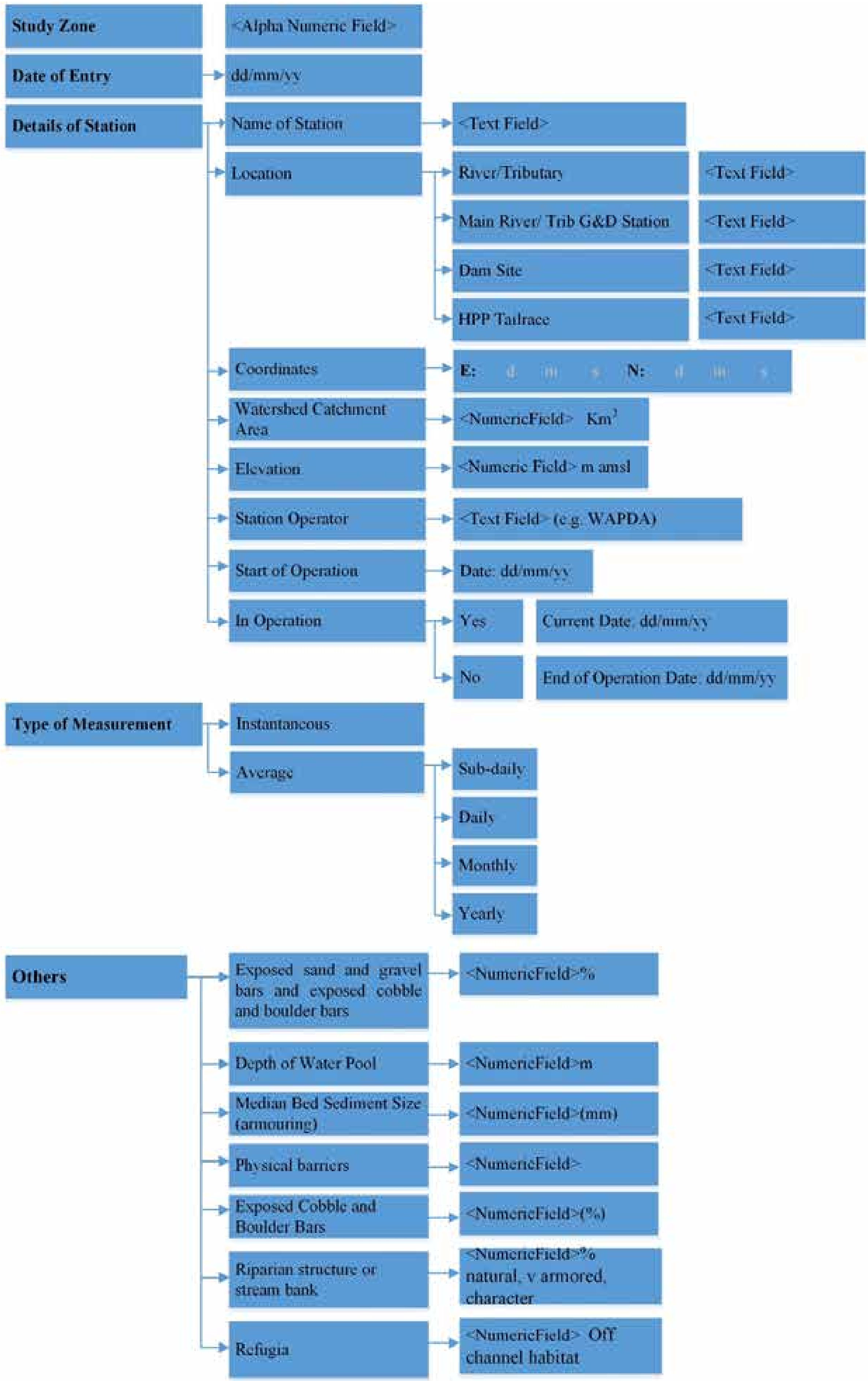
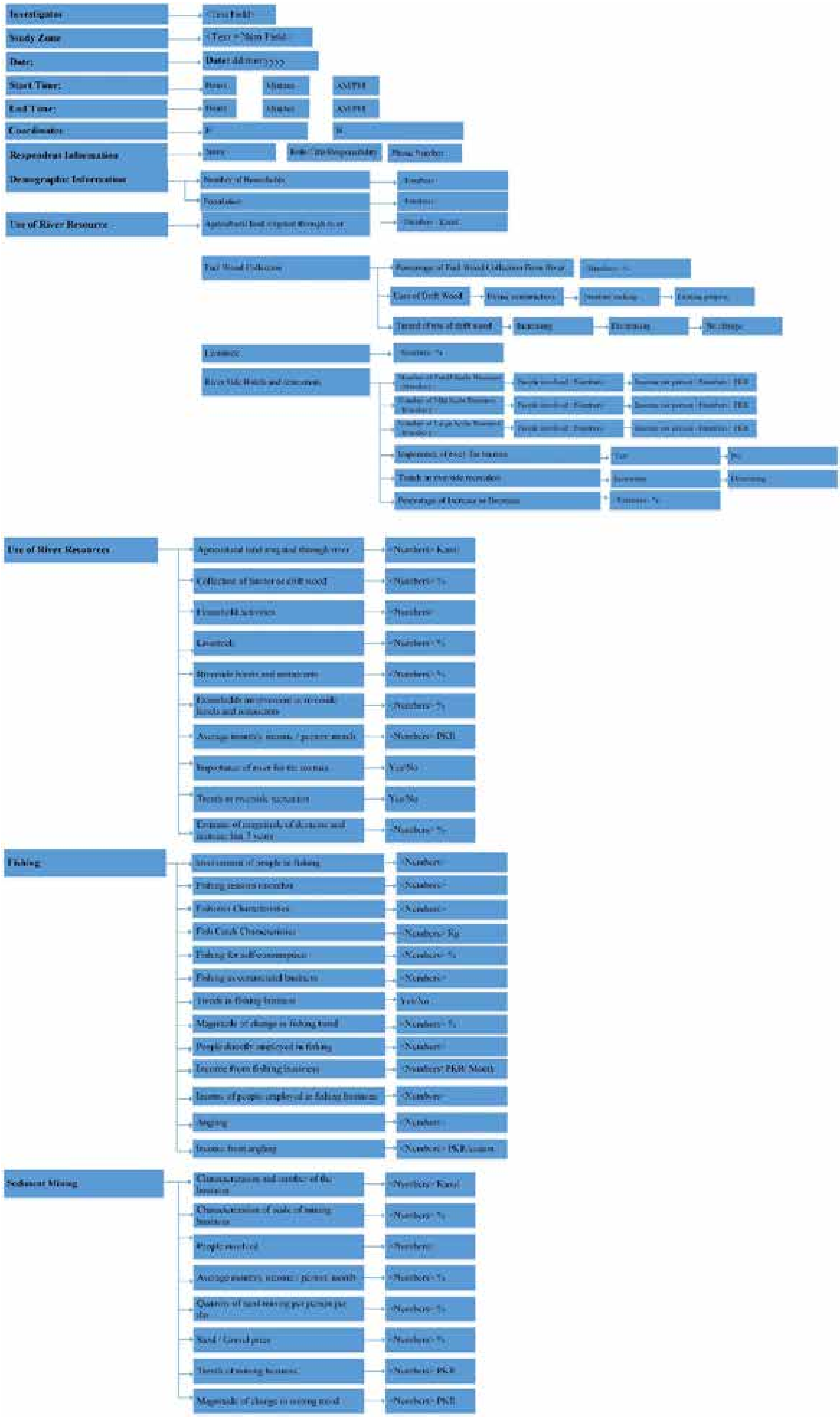


Figure H-5: Data Structure for Fish

Figure H-6: Data Structure for Macro-Invertebrates

Figure H-7: Data Structure for Periphyton

Figure H-8: Data Structure for Socio-economic




Awareness and Protection
Yes/No
Yes/No
Illegal hunting
Illegal fishing
Efficiency of protection
Increasing/Decreasing
Magnitude of change in forests
Lab And Field Water Analysis
Physical Parameters
Dissolved Oxygen (DO)
Total Dissolved Solids (TDS)
Monthly Temperature
Maximum Daily Temperature Series
Electrical Conductivity
pH
Aggregate Organics
Chemical Oxygen Demand (COD)
Heavy Metals
Cadmium
Lead
Mercury
Zinc
Iron
Nickel
Heavy Metals
Nitrate
Phosphate

Figure H-9: Data Structure for Water Quality – Physical Parameters at HPP and Gauging Stations

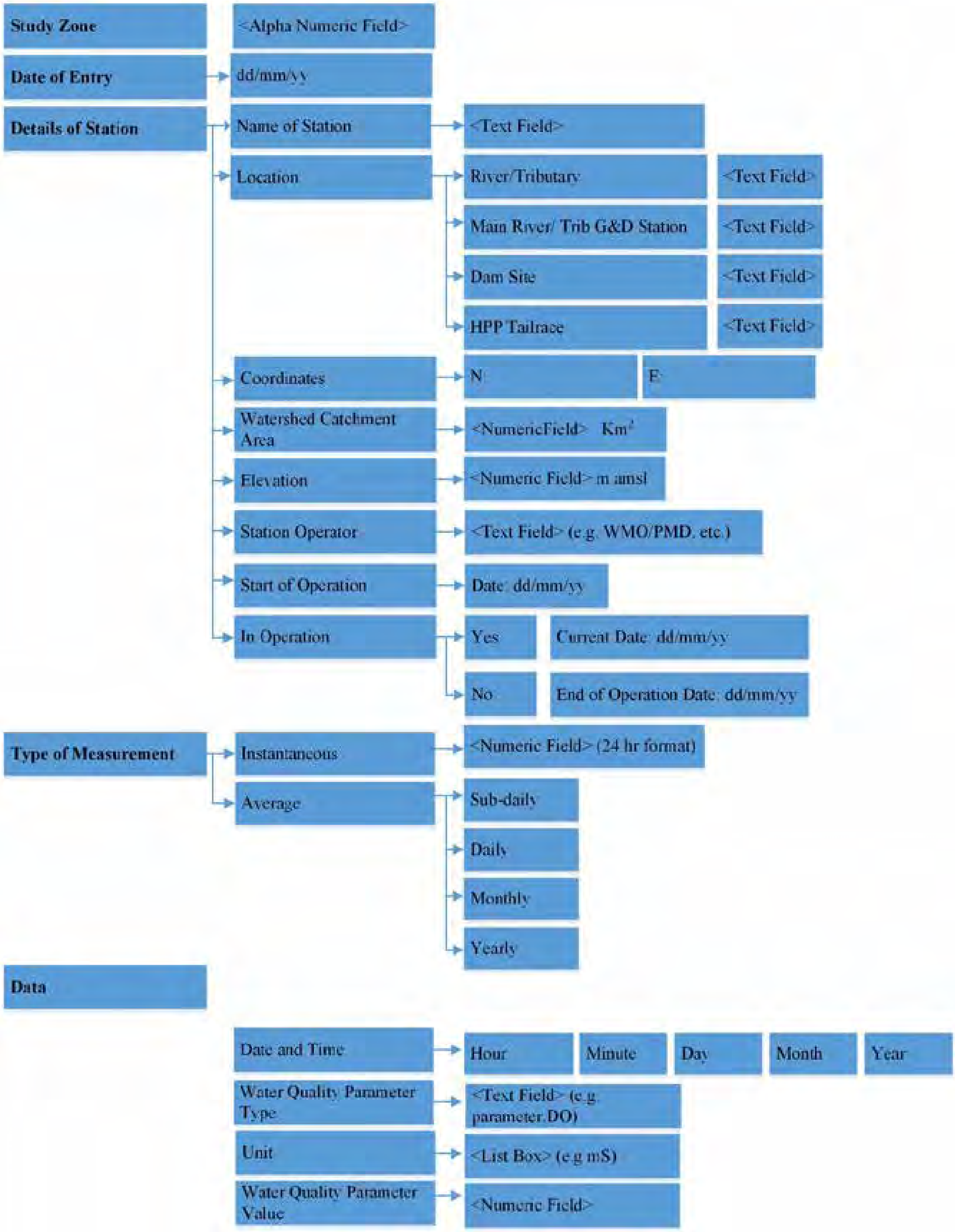


Figure H-10: Data Structure for Water Quality- Lab and Field Water Analysis

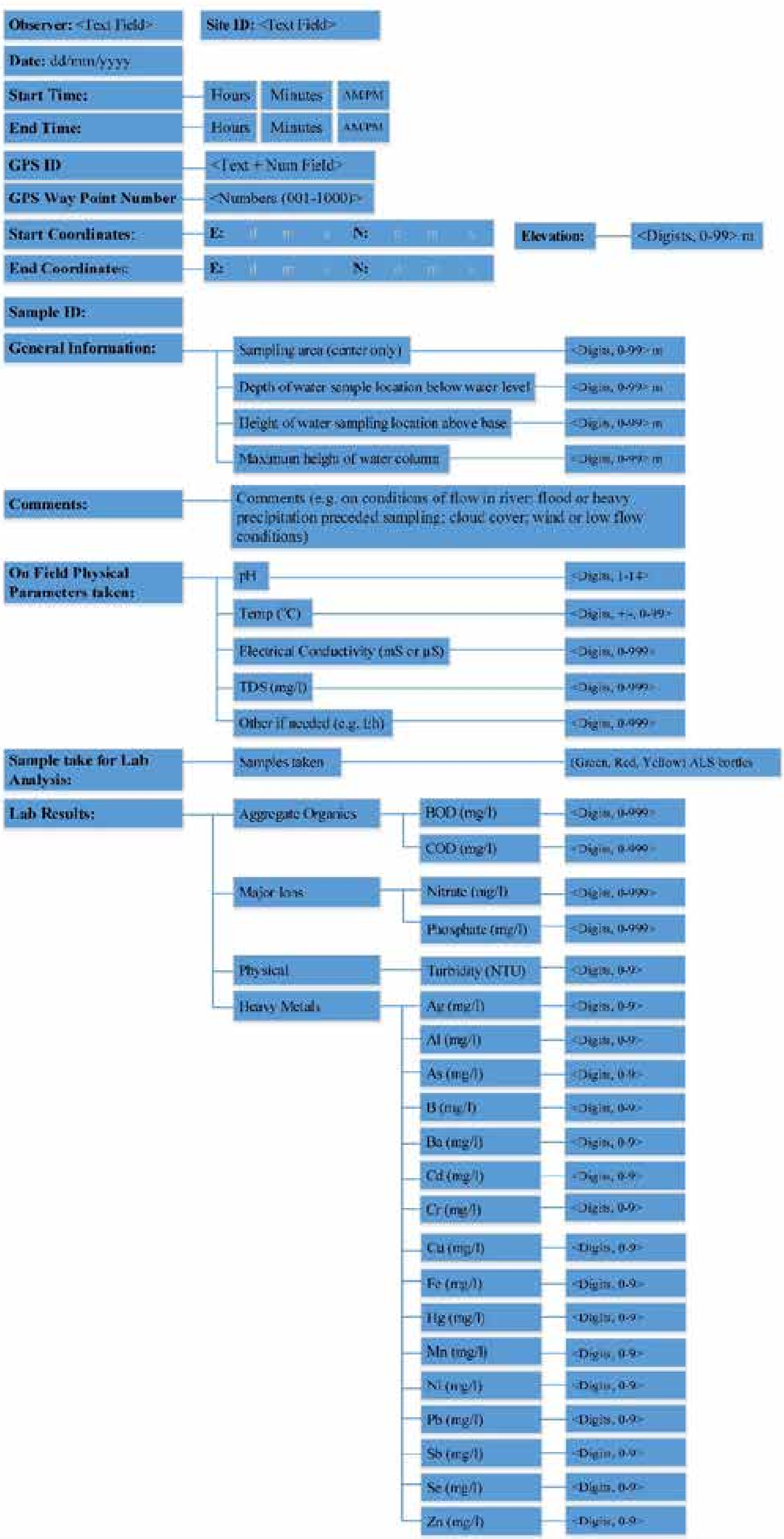


Figure H-11: Data Structure for Climate

Figure H-12: Data Structure for Hydropower Project Design

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