Situation of Embankments and Coordination of Flow of Water in the Indus River System at District, Province, and Federal Level Towards Tackling Flood Related Issues

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Abstract:

Pakistan has faced recurring floods over the past 75 years, with devastating impacts on land, lives, and the economy. The country has experienced 28 super riverine floods, resulting in extensive damage, loss of life, and economic losses. This study explores the role of various public sector institutions in managing water flows, flood protection infrastructure, and their coordination during floods. Focus is placed on the effectiveness of embankments, particularly along the River Kabul, and the influence of the Indus Water Treaty. By analyzing institutional frameworks, flood management strategies, and challenges in coordination, the research highlights the need for enhanced collaboration, improved early warning systems, and climate-resilient infrastructure. Additionally, the study calls for revising the Indus Water Treaty to better address climate change and water security concerns. The findings provide recommendations for improving flood management through better institutional coordination, advanced water management techniques, and more sustainable funding mechanisms.

Key words:

Flood management, Water security, Indus Water Treaty, Embankments, Climate resilience

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Introduction

In the 75 years of Pakistan's existence, the country has experienced 28 super riverine floods, affecting 616,558 km² of land, resulting in the loss of 13,262 lives, and causing economic losses of approximately $39 billion, up until the year 2020 (FFC, 2022). The 2022 floods affected around 33 million people across the country, with 3.2 million people affected in Khyber Pakhtunkhwa (P&D KP, 2022). Flood mitigation and preparation require a coordinated response from various institutions and public agencies mandated to deal with water-related disasters. In addition to coordinating relief and rescue activities, institutions also coordinate on a range of tasks such as managing water flows in rivers and canals, collecting and compiling early warning data, and making accurate predictions about potential floods. Pre-flood preparedness measures include the construction of flood protection infrastructure along vulnerable segments of the river plain to protect adjacent human settlements. Embankments or dykes along riverbanks are the most widely used flood protection infrastructure in the Indus River Basin. These works are carried out by multiple public agencies at both the federal and provincial levels. Over the last four decades, substantial investments have been made in developing these infrastructures, which have yielded significant benefits for communities at risk from floods. With the adverse impacts of climate change becoming more apparent with each passing day, new methods are being devised to enhance the effectiveness of these infrastructures, improve the quality of early warning systems, and take advantage of opportunities presented by transboundary water flow treaties.

Statement of Problem

Floods are a recurrent occurrence in Pakistan. Both federal and provincial governments have established institutions to manage and mitigate their impacts. These institutions coordinate at various levels on different aspects of disaster management. One such aspect is the coordination of water flow management during floods and in non-flood periods. The government also builds flood protection infrastructure to minimize these impacts, with Provincial Irrigation Departments playing a key role in developing and maintaining this infrastructure. This study will examine these aspects and analyze them through the following research questions:

1. What kind of coordination takes place between the relevant institutions regarding the control of water flows in the Indus Basin?
2. What role have embankments played in mitigating the effects of recurrent floods, and what return on investment have they provided, particularly at the River Kabul?

3. What influence has the Indus Water Treaty had on flood mitigation and water security for Pakistan?
4. How do provincial irrigation authorities perform in relation to the above aspects?

Scope of Study

This research will focus on public sector institutions in Pakistan, at both federal and provincial levels, that are responsible for controlling river water flows. It will analyze the framework administering the Indus Basin and the flood protection structures, particularly embankments, built by public agencies since 1978, with particular emphasis on the period following the 2010 floods.

Research Methodology

For the purposes of this study, a primarily qualitative research methodology is employed, utilizing both primary and secondary sources of information. Primary sources include a review of legislation and policies, departmental data, the development portfolio of provincial and federal governments (ADP/PSDP), domain knowledge, and key informant interviews with relevant resource persons from provincial irrigation departments, FFC, and IRSA. Secondary sources include published reports and academic studies.

The study will analyze various aspects of the research using the following analytical tools:

- Institutional analysis and stakeholder analysis
- Situational analysis based on PESTLE analysis techniques
- Policy analysis of policy instruments and action plans
- Comparative analysis with the 2010 floods
- Need assessment and gap analysis
- SWOT-EETH analysis

Analysis of Coordination Mechanism

This section will analyze the coordination mechanism between various levels of government to manage and control water flows in the Indus River System, particularly during flood seasons, through institutional, stakeholder, situational, and policy analysis:

Institutional Analysis

The management of water flows in the Indus River System is a technical subject, coordinated among specialized institutions at the federal and provincial levels. This section explains their institutional setup and roles in coordinating water flows, especially during the flood season, followed by stakeholder analysis:

- **Indus River System Authority (IRSA)**

Following the Water Accord of 1991, IRSA was established in 1992 under an Act of Parliament as the national body responsible for regulating and monitoring the distribution of water resources in the Indus River in accordance with the Accord. The Authority consists of five members, each nominated by the provinces and the Federal Government from among water engineers. IRSA's main function is to regulate and distribute surface waters, coordinating water flows as per the allocated shares between the provinces (IRSA, 2022). For this purpose, an Advisory Committee is established under Chapter-III of the IRSA Act, comprising technical representatives from respective governments. Under normal conditions, the Advisory Committee holds pre-Kharif and pre-Rabi season meetings to authorize water distribution to the provinces as per the Water Accord 1991. Special meetings are held during changes in hydrological patterns, such as water shortages or floods, to adjust water flows accordingly. During floods, the role of the Advisory Committee is minimized, and FFC and other disaster management bodies come to the forefront.

- **Federal Flood Commission (FFC)**

Established in 1977, the FFC is the premier national body responsible for managing flood administration across the country, preparing and overseeing the implementation of national flood protection plans, executing flood protection works, standardizing specifications, reviewing flood protection infrastructure damages, conducting research, and improving flood forecasting and warning systems. The FFC is the forerunner to IRSA and played a key role in negotiating the Water Accord of 1991 and preparing four ten-year National Flood Protection Plans (NFPPs). It is a technical body, led

by an Advisor/Chief Engineer, assisted by engineers, inspectors, and sectoral experts. Its primary role is to coordinate and advise during the flood season, holding meetings with stakeholders to review preparedness and advising the Ministry of Water Resources and IRSA on water flow regulation during floods. During the flood season, FFC sets up a flood monitoring cell that disseminates daily flood situation reports to relevant forums, leaving disaster response to NDMA/PDMA and provincial governments. FFC does not control water flows in normal times (Kamal, 2022). Additionally, FFC evaluates flood protection projects, issues standard designs for embankments, and recommends regulatory principles for Reservoir Management Committees (RMCs) (FFC, 2022).

- **Pakistan Meteorological Department (Flood Forecasting Division)**

The Pakistan Meteorological Department (PMD), one of the oldest departments in Pakistan, was established in 1947 to develop a comprehensive early warning system (EWS) for forecasting weather changes, cyclones, droughts, heatwaves, and floods. In 1978, PMD established the Flood Forecasting Division (FFD) in response to repeated flooding. FFD uses an extensive network of 97 observatories, 50 automatic weather stations, and 46 telemetry stations from WAPDA and provincial irrigation departments to predict flood occurrences and intensities (PMD, 2022). The data collected is relayed to IRSA, FFC, and other relevant institutions on a periodic and real-time basis during floods. While the EWS has been useful, it has not been optimally utilized. Recently, the system was upgraded to include hydrological models for the River Swat and Kabul basins, from Warsak to Nowshera.

- **Water and Power Development Authority (WAPDA)**

Established in 1958, WAPDA is the federal government's lead executing agency for water resources. WAPDA manages gauge stations at major rivers to collect hydrology data. Its main role in water flow management is to implement decisions made by IRSA, FFC, and Reservoir Management Committees (RMCs). FFC also assisted WAPDA in deploying a Meteor-burst-based telemetry system across Pakistan, which transmits hourly rainfall and river level data to IRSA, FFD, and FFC. WAPDA is also responsible for managing water flows from major reservoirs, with reservoir management committees formed to establish standard operating procedures (SOPs) for flood situations (FFC, 2017).

- **Reservoir Management Committees (RMCs)**

As per international best practices, RMCs are formed for all large reservoirs with clear SOPs for water flow management. These bodies make decisions on

spillway control during floods, authorizing changes in water discharge from reservoirs. In Pakistan, two such committees exist for Tarbela and Mangla Dams. These committees are composed of representatives from WAPDA, IRSA, FFC, PMD, NESPAK, respective provincial governments, and district administrations. SOPs are periodically revised, particularly after major flooding events, incorporating lessons learned. Under normal conditions, releases from reservoirs are made as per IRSA's instructions, whereas during floods, releases are determined by RMCs, considering advice from forums such as IRSA, NDMA, and FFC, with a priority on reservoir safety, water storage, energy generation, and flood mitigation (WAPDA, 2015).

- **Provincial Irrigation Departments (PIDs)**

Provincial irrigation departments (PIDs) are the primary operational arms in flood forecasting and management. PIDs collect real-time hydrology data through gauge stations and share it with relevant agencies such as IRSA, FFC, PDMA, and district administrations. Normally, this data is shared on a ten-day basis, but during floods, the frequency of reports increases to daily and even hourly intervals. Currently, data collection is mostly done through manual gauge readings, though provinces have begun deploying digital telemetry systems for real-time data streaming (Kamal, 2022).

- **Pakistan Commissioner for Indus Waters**

Under the 1960 Indus Water Treaty (IWT) between India and Pakistan, a Permanent Indus Water Commission was established, with each country appointing a commissioner. In 1989, an agreement was made to share river flow data for flood forecasting. The Pakistani Commissioner receives daily flow data from India, and during floods, this frequency increases to six-hourly or hourly updates. This data is then relayed to FFD Lahore and IRSA for flood forecasting in the Jhelum, Chenab, Sutlej, and Ravi rivers. The Indus Water Commission is the sole point of contact for hydrology data clarification from India. However, no such arrangement exists for sharing data from Afghanistan regarding the Kabul River (Irshad, 2022).

- **National and Provincial Disaster Management Authorities**

The national and provincial disaster management authorities (NDMA and PDMA) are not directly involved in water flow management but play a vital role in pre-flood preparedness, disaster mitigation, and coordinating post-flood rescue, relief, and rehabilitation efforts. NDMA and PDMA remain in constant communication with the aforementioned bodies to obtain real-time flood data to plan and execute mitigation strategies effectively.

Stakeholder Analysis

It is crucial to analyze the role, influence, and interests of the stakeholders involved in managing water flows under normal and flood situations, along with the coordination strategy employed. The stakeholder analysis is enumerated in the table below:

Stakeholder	Power/Influence	Interest	Coordination Strategy
IRSA	Allocates and monitors water resources in the Indus Basin as per the Water Apportionment Accord of 1991. Reviews and specifies river and reservoir operation patterns. Passive role during floods.	Maintain harmony in water distribution among provinces. Ensure fair distribution of water resources.	Periodic meetings of the Advisory Council, including before the start of each cropping season. Implements water discharge advisory to WAPDA and reservoir management guidelines/SOPs.
FFC	Monitors and evaluates flood response efforts. Disseminates daily flood situation reports and weather advisories during floods. Prepares and coordinates the implementation of NFPPs and oversees flood forecasting and management.	Ensure the implementation of national flood protection plans in coordination with federal and provincial bodies. Ensure a coordinated response during floods.	Pre- and post-monsoon/flood season meetings of the Commission. Establishes a Flood Communication Cell for daily flood situation reporting during floods.
WAPDA / RMCs	Operates and manages reservoirs. Collects and processes hydrometeorological data. Issues advisory in discharge of water	Protect reservoirs and their associated infrastructure. Ensure optimal filling of storage and continued energy	Regular meetings at WAPDA HQ, issuance of seasonal instructions to RMCs. Disseminates

	flow from dams during floods.	generation. Protection from floods.	flood levels at reservoirs to flood response agencies.
Provincial Govts./ District Admins.	On-ground execution of national or provincial water policies. Declaration of emergency and mobilization of relevant flood response agencies. Provision of human, material and machinery resources.	Protection of lives and property. Control losses to infrastructure and livelihoods. Ensure continued supply of allocated share of water and electricity.	Collates and disseminates daily situation reports. Superintendence of flood response through Cabinet. District disaster management authorities coordinate efforts of line agencies.
Provincial Irrigation Departments	Construct, manage, operate, and maintain barrages and flood protection works. Diversion of water in distribution networks.	Protect canals, barrages, and drainage systems. Protect water resources by conserving, redistributing, augmenting, and allocating water.	Inter-Provincial coordination through IRSA, FFC. Sharing of real-time data with FFD(PMD), field formations. Enforcement of water laws. Collection of hydrology data.
NDMA / PDMA	Not directly involved with water flow management. Their role pertains more to pre-flood preparedness, disaster mitigation, and coordinating post-flood efforts.	To ensure timely coordination and response to floods. Enhance disaster preparedness and mitigation efforts.	Active communication with stakeholders like FFC, IRSA, and provincial authorities. Coordinates post-flood relief and recovery efforts.
Permanent Indus Water Commission	Coordinates with India on water flow in trans-boundary rivers under the IWT (1960). Relies on relay of	Timely reporting of trans-boundary water flow data.	Daily reporting of telemetry data from Indian counterpart. Dissemination to FFD, IRSA.

	information from India.		
Flood Forecasting Division (FFD), PMD	Collects and collates weather and hydrology data, forecasting through climate models. Issues rain advisories and flood warnings.	To accurately forecast rains and floods. Ensure timely dissemination of reports/warnings to stakeholders.	Real-time collection of data and weather modeling.

Situational Analysis

The flood management regime in Pakistan operates in a dynamic environment influenced by various external factors. The PESTLE analysis helps identify the opportunities and challenges within this environment:

Factor	Description
Political (P)	- There is strong political support by political leadership towards flood management, across party lines. - There is strong commitment and consistency of government in the provision of funds for flood mitigation and other support. - The National Flood Protection plans have support from all provinces and the federal government. Approved by CCI. - However, some projects of flood management are driven more by political considerations than based on need assessment.
Economic (E)	- The country's weak economic position does not permit greater fiscal allocation towards flood mitigation measures. - Disasters like the 2022 floods incur large damages with huge financial requirements. 2022 flood damages were estimated at Rs. 3,202 billion. - Due to repeated disasters, donor fatigue has set in, with donor assistance dwindling. Against the total UN flash appeal of $816 million, only $170 million have been committed by international donors. - Other than damage to public infrastructure, there are private losses, livelihood losses, and income

	loss. - The agrarian economy of the country has suffered a huge loss of Rs. 800 billion to crops and livestock.
Socio-Cultural (S)	- Social disregard for the nature and ecology of rivers, resulting in constriction of river flows. - Society already has income disparities, which are likely to be aggravated by disasters like recent floods. - Children, women, and the poor are the most vulnerable segments of society in the event of any disaster. - Diversion of scarce resources for rehabilitation is likely to attenuate the socio-economic disparity. - The incidence and culture of donations for public causes and relief efforts is high in Pakistan. Alternate delivery channels through direct assistance or through NGOs supplement the efforts of governments.
Technological (T)	- Traditional and manual gauge reading techniques are used for collecting hydrology data. - Warning messages are disseminated predominantly through community-based traditional methods like mosque announcements. - There is a desire and commitment of resources to gradually shift to modern telemetry and technology-based Early Warning Systems (EWS). - Latest modelling software is being procured by PMD and FFC for accurate mapping, forecasting, and dissemination of weather data.
Legal (L)	- Well-defined laws, regulations, and SOPs are in place for defining the institutions involved in flood management, their roles, and operations. - Realizing the importance of water resources, policy instruments are being developed. The first National Water Policy has been approved. FFC regularly prepares actionable ten-year plans detailing all aspects. - Enforcement of water laws is very weak, partially due to capacity constraints and partially due to discouragement and low penal actions from judicial forums.

Environmental (E)	- In addition to affecting human settlements, floods cause unprecedented damage to local flora and fauna. - Floodwaters bring large quantities of silt deposits, which are beneficial for agricultural lands but damaging for settlements. - Floodwaters intermix with hazardous waste and sewage from drains, contaminating large areas of cultivable land. - In the past, deforestation has accelerated climate change and soil erosion, triggering flash floods and Glacial Lake Outburst Floods (GLOFs). - Realization and increased focus on tree plantation are likely to reverse the negative effects of earlier deforestation.

Policy Analysis

At the national level, there are two policy instruments in place: the National Water Policy, 2018, formulated by the Ministry of Water Resources, and the 4th National Flood Protection Plan, 2017, formulated by the Federal Flood Commission. Apart from these, there are no flood-specific policies at the federal or provincial level relevant to the coordination of water flow mechanisms between different stakeholders. These policies are analyzed as follows:

National Water Policy, 2018

The Government of Pakistan approved the first National Water Policy in 2018 to address the emerging water crisis, especially in the wake of climate change. The policy aims to provide a framework and guiding principles to institutions working in the water sector. Under Pakistan's federal structure, water resources are a national subject, while environment, irrigation, agriculture, and related water sub-sectors are provincial subjects. The Policy attempts to harmonize their efforts and provides a list of objectives to be achieved collectively. It also outlines strategic priorities and national targets for water conservation, storage, and usage. However, these policy targets are not binding on provincial governments unless confirmed by the provinces before their incorporation into the national planning framework (12th and 13th Five-Year Plans).

The policy mandates that at least 10% of federal PSDP (Public Sector Development Program) funding be allocated to the water sector, gradually increasing to 20% by 2030. It also calls upon provinces to increase their

respective allocations for the water sector (MoWR, 2018). In the 2017-18 PSDP, the water sector received only 4% of development funds, but this allocation has subsequently increased to 11.3% (Rs. 91.6 billion) in the 2022-23 PSDP. To achieve its targets, the Policy recognizes the need for a robust implementation plan with clear responsibilities and a transparent reporting process. The establishment of a National Water Council is fundamental to mitigating inter-provincial tensions arising from water distribution and addressing social, environmental, and economic safeguards in managing Indus River Basin water resources.

The policy document briefly touches upon water-related hazards, including floods and seawater intrusion. However, the policy recommendations focus on developing flood protection plans, floodplain mapping and zoning, and the construction of flood protection infrastructure. The only policy measure relevant to floodwater management is the recommendation for the revision of reservoir operation rules. It does not specifically address the coordination mechanism for water flow management in rivers. The Policy could have provided a perspective on transboundary water management with Afghanistan, following the pattern of the Indus Water Treaty (IWT). Realizing the objectives of the Water Policy would require significant investment, for which a financial plan, like the one in the 4th NFPP of FFC, could have been provided.

4th National Flood Protection Plan, 2017

The FFC issues a policy document in the form of ten-year national flood protection plans, with the 4th NFPP being the latest, approved in 2017. The plan was prepared jointly by national and international consultants from the Netherlands, a country that has successfully managed high water levels in its urban landscape throughout its history. The plan has the consensus of all federating units and was approved after thorough consultations and deliberations by the Council of Common Interests (CCI). The plan encompasses all five major types of flooding prevalent in Pakistan: (i) riverine floods, (ii) flash floods in hill torrents, (iii) coastal floods, (iv) urban floods, and (v) glacial lake outburst floods. One of the unique features of the 4th NFPP was the preparation of a national inventory of flood protection infrastructure. In addition to listing the required infrastructure works, the plan also provides a flood protection investment plan, detailing the financial resources required over a ten-year period and the sources of funding. The plan proposes a shift from public funding to raising revenues through water charges, irrigation cesses, and other taxes, with an estimated revenue collection of Rs. 60 billion from water charges (FFC, 2017).

The plan discusses both structural and non-structural measures required for flood protection. Structural measures are easier to implement, are visible, and

show early results. However, the past three NFPPs have been partially successful in achieving their targets. Of the 2014 proposed flood protection schemes in the three plans, only 874 schemes were completed by 2017, leaving a large backlog. Table-1 lists the federal investments in flood protection works/schemes completed by 2017:

Plan	Time Period	Proposed Schemes		Executed Schemes	
		No.	Cost *(Rs. Mn)*	No.	Cost *(Rs. Mn)*
NFPP-I	1978-88	840	9,500	311	1,730
NFPP-II	1988-98	735	8,500	180	1,419
NFPP-III	1998-08	439	11,703	383	4,292
Total		**2014**	**29,703**	**874**	**7,441**

We observe that despite such a large investment, the 2010 and 2014 floods caused widespread damage. The 4th Plan proposes a range of structural measures, such as the construction of embankments, gabions, diversion channels, and lining of drains. The plan also details the criteria for scheme proposals, selection, and prioritization. As of now, 582 schemes worth Rs. 91 billion are included in the 4th NFPP. The provinces have further proposed additional works amounting to Rs. 194 billion (FFC, 2017). Given the pace of development, resource availability, and the remaining time until 2027, it remains to be seen if the current plan will be able to execute the proposed projects.

Non-structural measures, on the other hand, require behavioral change on the part of all stakeholders, are not as attractive or resource-intensive, and, given the psyche of the nation, are difficult to implement. Encroachment on floodplains, sewage dumping in city drains, and the blockage of drainage paths require determined laws, regulations, policies, and implementation. The 4th NFPP presents a range of proposals for non-structural measures and 28 schemes costing Rs. 14 billion. One of the most significant policy proposals is the draft River Act, which is to be enacted by the four provinces. Although the Government of Khyber Pakhtunkhwa (GoKP) promulgated the Rivers Ordinance in 2002, much before FFC recommended the legislation, its implementation in the province has been sketchy. The Plan also discusses strengthening of the Early Warning System (EWS) according to the density standards of the World Meteorological Organization (WMO).

However, the plan does not provide any guidelines or mechanisms for better coordination among the different stakeholders engaged in water flow management, especially during the flood season. The role of coordination is taken over by the RMCs during floods, for which the plan only mentions revising their SOPs, without providing any tangible recommendations.

Analysis of Embankments in The Indus River System

Embankments are flood protection levees or dykes, also known as bunds in the local language. They are large earthen wall-type structures built at the edges of the active floodplain of a river to confine its flow within a specified area, preventing water from spilling over and causing flooding. Embankments constitute the bulk of flood infrastructure in the Indus Basin. They increase the channel depth and cross-sectional area of the river, thereby increasing its hydraulic radius and water-carrying capacity.

Embankments in The Indus River Basin

Province	**Embankments (km)**
Punjab	3,334
Sindh	2,424
KP	352
Balochistan	697
AJ&K	13
Total	**6,820**

Table-1: Length of Embankments

To safeguard the areas from inundation, approximately 6,820 km of embankments have been constructed along the major rivers and their tributaries in the Indus Basin. These embankments have gradually improved with the development of barrage-controlled irrigation and have expanded to protect irrigated agriculture and the population. The length of constructed embankments, province-wise, is given in **Table-1**.

In KP, floods are mainly caused due to flash flooding in secondary rivers (Kabul, Swat, Panjkora, Kurram, etc.) and major hill torrents generating nullahs, which have steep bed slopes that increase water velocity, thereby causing inundation across the banks. Many spurs and flood embankments/flood protection walls in critical locations have also been constructed along the Kabul, Swat, Panjkora, and Kurram rivers, as well as their tributaries, including flood flows generating nullahs/hill torrents. Their details are given in **Table-2**.

Structure	**No.**

Embankments	105
Flood Walls	455
Spurs	223
Dispersion Structures	1
Total	**784**

Table-2: KP Flood Protection Structures

NEED/GAP Assessment of Embankments

River/Basin	No. of Schemes	Estimated Cost (Rs. Mn.)
Indus	45	13,546
Kabul	22	3,704
Swat	5	2,750
Total	**72**	**20,000**

Table-3: Proposed Additional Works for KP

Based on a 2018 study that modeled data to predict flooding, it was concluded that there is an increasing trend in flooding due to rising precipitation and higher temperatures. The current flow with a 1-in-50-year return period is likely to occur five times more frequently (i.e., once every 10 years) in the future (Iqbal et al., 2018). The 4th NFPP proposes the construction of 582 flood protection schemes/embankments across the country to control spill and erosive action in vulnerable reaches of the rivers. An estimated amount of Rs. 91 billion would be required over a 10-year period to fund the construction of these schemes. However, provinces have proposed additional flood protection works, which were duly approved by the CCI, bringing the total cost of such works to Rs. 194 billion, to be financed by federal and provincial governments on a cost-sharing basis (FFC, 2017). For Khyber Pakhtunkhwa, flood protection works required for the Indus River Basin, including the Kabul and Swat Rivers, are listed in **Table-3**.

Analysis of Embankments in The Indus River Basin

Additionally, these levees have been constructed gradually over six decades under various programs, and thus differ in design and construction quality. At some locations, construction has caused sedimentation and aggradation of the riverbed, which may require a continuous increase in the heights of the levees. Likewise, wetting channels, which were built along these structures to test their strength against water leaks, are now largely non-operational. Consequently, their structural weaknesses cannot be determined before actual flooding. Other challenges include their remote locations, inadequate maintenance, and continuous degradation due to natural and human factors.

Flood embankments are mostly appropriate for floodplains that are already intensely used, in the process of urbanization, or where the residual risks of

intense floodplain use may be easier to handle than the risks in other areas (e.g., landslides or other disturbances). Since embankments cannot guarantee absolute flood prevention, they are designed to provide only a moderate level of protection. The degree of protection is generally driven by economic considerations. For instance, it may be appropriate to protect agricultural lands against floods of a one-in-ten-year return period and allow them to be inundated during higher floods, thus still maintaining the natural benefits of flooding (e.g., delivery of nutrients and organic-rich sediments). In Pakistan, the height of embankments is often arbitrarily determined at a height of 6 feet above previously observed high flood marks (Shireen, 2022). However, due to morphological changes in the rivers, flood stages do not necessarily have a linear relationship with the quantity of floodwater. Thus, scientific data is needed to accurately determine the optimal levee height. The existing barrages, designed for a 100-year return period, performed better in flood protection.

By containing flows within embankments and impeding seasonal floodplain inundation, the active floodplain that was previously exposed to inundation is restricted. This disrupts the lateral hydrological connectivity along the river corridor, with various effects on both the ecology of the channel and its floodplain. Floodwater spreading onto the floodplains improves soil fertility by depositing silt, exchanging nutrients and carbon between the floodplain and the channel, creating new habitats, reinstating floodplain refuges, and providing spawning areas for river species. Embankments reduce floodplain fertility because sediments and their nutrients are no longer deposited and exchanged.

Instead of using traditional embankments, the FFC has developed a draft concept proposal regarding the use of a Tube Barrier System, an innovative solution being used by European countries like Hungary and Denmark. It consists of rubber tubes filled with water to act as temporary walls to divert flood flows for the protection of important installations, land, and settlements. The draft Concept Paper has been circulated to all provinces and federal line agencies for their views/comments and further adaptation of this new innovative technology (FFC, 2020).

For the Swat and Panjkora rivers, a comprehensive plan for the development of embankments, similar to that of the Kabul River, is absent. Embankments around these rivers are built on an ad-hoc basis and constructed over time as needed, with varying strengths and lengths. Hence, these embankments do not provide the same level of protection against floods as those along the Kabul River.

Role Of Embankment Along the Kabul River

In the aftermath of the 2010 floods, the GoKP launched an ambitious project to erect embankments along both sides of the Kabul River, from Warsak Dam to Khairabad at Nowshera, the point where the Kabul River joins the Indus River. Initially, the length of these structures was planned at 70 kilometers but was later revised to 105 km. The embankment is being constructed at a cost of Rs. 13 billion, funded through the ADP, and to date, almost 80% of the work has been completed (Shireen, 2022). An amount of Rs. 3.3 billion is required to complete the remaining work.

Analysis of The Embankment at Kabul River

The 2022 floods were the first real test of the Kabul embankment, which faced peak flows of 349,000 cusecs near Nowshera. The structure has been beneficial in terms of curtailing losses to human settlements around the river plain, as observed when compared to the damages sustained in the 2010 floods. Therefore, the project has a high rate of return on the investment made. The reduction in losses very well compensated for the costs incurred in its construction.

The embankment was designed to carry 215,000 cusecs of water, based on a 100-year return period, but it was able to successfully sustain water flow up to 281,000 cusecs during the 2022 floods, after which floodwaters spilled over. Of the entire length of the constructed embankment, only one major breach occurred near Manakhel, Nowshera Kalan, which initially was 40 feet wide, but the deluge expanded the breach to 200 feet. Overall, the embankment sustained moderate damage, calculated at Rs. 1.1 billion (Shireen, 2022).

The entire embankment was constructed on negotiated private lands, and no land acquisition took place for its construction. However, there are some unresolved gaps, primarily due to land disputes and litigation, with major ones at three places. The largest of these openings is 750 meters wide, which was a major cause of water spillover onto adjoining lands. The Irrigation Department, with the assistance of the District Administration, is actively negotiating to settle these disputes out of court, and work has resumed on filling these gaps. Secondly, some smaller gaps are caused by the local population for cattle crossing or accessing grazing areas. Finally, due to resource limitations, the openings of nullahs and tributaries into the Kabul River were left ungated, resulting in the backward flow of water into these channels. To mitigate this, the Irrigation Department has initiated the installation of Valve Flood Gates on these openings, with three gates already installed at Garhi Momin drain and Zakhai drain. The installation of similar gates at 20 more locations is planned at a cost of Rs. 71 million. Once

completed, this issue of backward flow is likely to be resolved to a large extent (P&D, 2022).

Due to the construction of the Kabul embankment, a large area of cultivable land has been reclaimed—approximately 33,469 acres on the Nowshera side and 9,278 acres on the Charsadda side—enabling cropping on these reclaimed lands. However, a negative consequence of the assurance against deluge has prompted people to start constructing restaurants and other built-up structures (Kamal, 2022).

Need For Additional Works

Realizing the benefits of the embankment along the Kabul River, the provincial government has planned the construction of an additional 58 kilometers of embankment, raising the existing average height from 20 feet to 24 feet, and incorporating elements of climate change resilience. The cost of these additional works is estimated at Rs. 14 billion, which would be collectively financed by the GoKP and the Federal Government (PSDP allocation for the 4th NFPP), along with international funding from the Asian Development Bank. Upon completion of these additional works, the carrying capacity of the river would be raised to 320,000 cusecs (FFC, 2017).

Comparative Analysis With The 2010 Floods

Details	**2010**	**2022**
Max Water (cusecs)	436,000	337,000
Villages affected	40	31
Affected Population	571,221	250,000
Evacuations	350,336	67,917
Human Loss	167	3
Livestock Loss	67,000	0
Houses Damaged	67,940	19,736
Crops Damaged (Kanal)	59,000	46,553
Flood Protection Wall	No	Yes

The 2010 floods serve as a benchmark in recent times to evaluate the extent of flood damages and the role played by the embankment along the Kabul River. **Table-4** compares the water levels and the extent of damages between the 2010 and 2022 floods. We observe that the extent and magnitude of damages in 2022 remain comparatively low. The geographic spread of the 2022 floods in and around Kabul was less than 50% of the 2010 floods, as visualized in **Fig-1** (GIS Hub, 2022). In terms of the number of villages affected, there was a reduction of 25%. The affected population decreased by 56%, with very little human loss, and evacuations were reduced by 81%. Some of the damages to

infrastructure were caused due to the direct impact of floodwaters on structures erected within the active floodplain.

Fig-1: Comparison of flood span Nowshera: 2010)and 2022 ( )

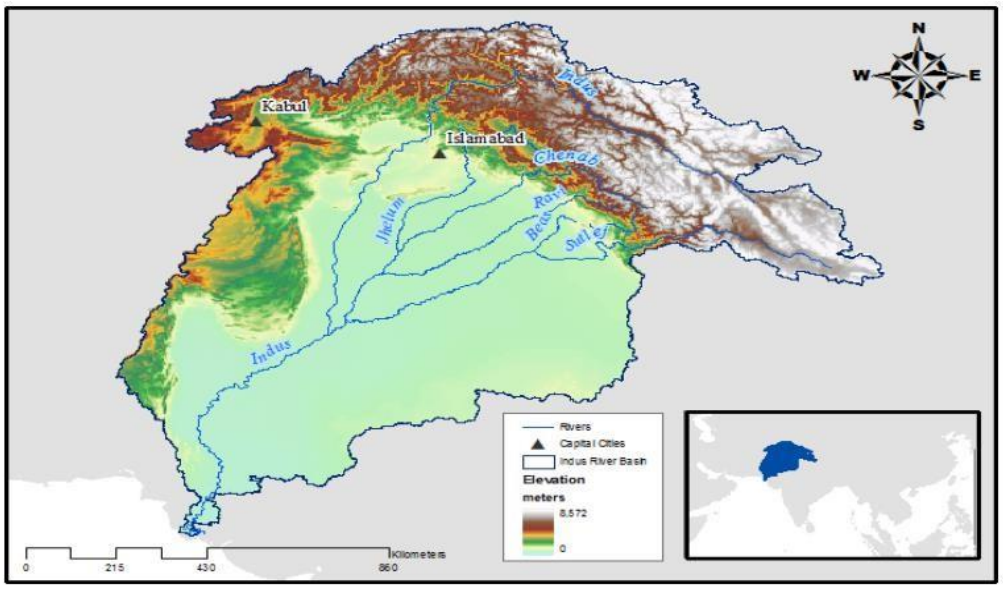
We also observe that the extent of damage to houses was almost one-third of that during the 2010 disaster, and there was almost no loss to livestock. The contributing factors that can be identified for the lower damages are: (i) the construction of the flood protection wall alongside the riverbank, and other drainage infrastructure costing Rs. 19 billion in Nowshera, (ii) better preparedness and timely planning by the provincial government and district administration, (iii) swift evacuations and effective use of the early warning system, and (iv) management of water discharge levels in the River Indus through joint coordination mechanisms.

Analysis of Indus Water Treaty

The Indus River basin originates from Tibet in China and passes through Indian-held Kashmir before entering Pakistan, finally falling into the Arabian Sea near Karachi. Its five major tributaries join the Indus in the Punjab province of Pakistan. Soon after the independence of British India, a dispute arose between India and Pakistan in 1948 over the distribution of river waters, when India halted the supply of water flowing into canals irrigating lands in Pakistan. After lengthy negotiations between the two riparians, and under the auspices of the World Bank, an accord named the Indus Water Treaty (IWT) was signed in 1960, which divided the basin by granting unrestricted use of three western rivers – Indus, Jhelum, and Chenab – to Pakistan, and three eastern rivers – Ravi, Sutlej, and Beas – to India. The treaty established the offices of the Permanent Indus Water Commissioner in each country for coordination and information exchange related to river flows. The World Bank, with financial support from the USA, UK, New Zealand, Germany, and Australia, funded the construction of irrigation infrastructure for water

storage and distribution in Pakistan to compensate for the loss of the three eastern rivers.

The IWT is considered one of the world's most successful treaties, which has remained intact for sixty years and survived three wars between the two arch-rival riparians.



Although the treaty holds intact, there have been advantages, disadvantages, and complexities regarding the Treaty and its implementation. These are listed as:

Strengths of The Treaty

i. The treaty divided the water source available between the two riparians, and upon completion of replacement irrigation works, allowed them to independently manage their water supplies.

ii. Each country became responsible for planning, constructing, and administering its own irrigation system. This incentivized the most effective use of its water resources, enhanced efficiency, and increased storage capacities. Pakistan was able to increase its water storage capacity, thereby increasing canal water diversions from 67 MAF to 104 MAF.

iii. The treaty reduced disputes and acrimony between the two states and allowed independence and assurance against interference from the other.

iv. The Indus Basin Irrigation System is based on the run-of-river system, which allowed for more storage facilities to cater to seasonal variations.

v. The hydrology of the Indus Basin enabled the availability of 80% of the total water during the monsoon period. With storage now available in reservoirs, water availability is also assured during dry/drought periods.
vi. A Permanent Indus Water Commission was established with Commissioners from each country, with a moderately reliable mechanism for the peaceful resolution of water-related conflicts.
vii. The treaty has prevented India from cutting off the water supply to Pakistan on an ad-hoc basis, even in the face of political pressures.

Weaknesses and Pitfalls

i. The Indus Water Treaty is not considered the first best option from the perspective of both countries. Pakistan was allocated 75% of the water, as opposed to 90% of irrigated land, violating the principle of appreciable harm. India's perspective is that the 75% allocation of water to Pakistan violates the principle of equitable utilization.
ii. Pakistan had to forego the entire perennial flow of fresh waters from the eastern rivers (24 MAF), which it historically used for irrigation. Storages are not substitutes for perennial flow, as they have a limited lifespan. Pakistan is already facing the effects of silting in its major reservoirs and canals.
iii. The IWT lacks a strong enforcement mechanism, and therefore is influenced by the regional balance of power. In the case of disagreement, differences are to be resolved bilaterally through the Permanent Indus Commission, and upon failure, the matter is to be referred to the International Court of Arbitration. The World Bank is the guarantor of the IWT; however, its role is only as a conflict solver. The guarantor relies on the riparian to report any issue related to illegal intervention in river flows. However, there is no definite way of knowing if illegal intervention really occurred, or if it is merely a case of low seasonal flows due to climate variability.
iv. Pakistan is particularly concerned regarding two Indian projects: Baglihar and Kishenganga hydroelectric dams. Both projects have become emotive issues for Pakistan, as there is a perception that India can affect the timing and flow of water into Pakistan using these structures.
v. Every now and then, there's a commotion in India about repealing the IWT as a comeback to terrorism incidents blamed on Pakistan. In 2016, India reviewed the working of the Indus Water Treaty, linking it with cross-border terrorism. "Blood and water cannot flow concurrently," PM Narendra Modi stated after the Uri attack, indicating to Pakistan that such terrorist incidents would lead to India rethinking its stance on the IWT.

Impact On Water Security

Water security may be defined as the allocation rules that ensure adequate water availability or a nation's ability to protect its inhabitants from the adverse effects of water shortages. In the context of transboundary waters, like in the case of India and Pakistan, countries have defined water security as securely attaining specific quantities of water every year.

The Indus River System is a lifeline for Pakistan, and nature has endowed the country with plenty of fresh water. However, despite having the world's largest glaciers and five rivers covering the country's plains, Pakistan is among the world's most water-stressed countries. According to the Pakistan Council of Research in Water Resources, Pakistan became a water-stressed country in 2005 and is likely to become water-scarce by 2025. The growing population and rapid urbanization are major factors in the five-fold decrease in per capita water availability, from 5229 cusecs in 1947 to under 1000 cusecs today. Adverse climatic conditions like heatwaves and erratic monsoon patterns are also taking their toll on glaciers, which are melting fast. Furthermore, water management has become wasteful and inefficient, especially due to the expansion of tube-well irrigation and the use of traditional techniques of flood irrigation over modern and efficient irrigation techniques.

The Indus water basin is very sensitive to climate change impacts, as a large part of its water flow is derived from melting glaciers. This has resulted in changes in hydrology patterns, flooding in some years, and water scarcity in others. The IWT was negotiated in 1960, and there is no mention of tackling the impact of climate change. Trust in the treaty and its utility is being eroded due to the climate change phenomenon. It lacks guidelines to address issues related to climate change and basin sustainability, which require an integrated approach for their resolution.

The treaty grants Pakistan unrestricted access to the water of three western rivers, and India non-consumptive access to the three eastern rivers. Pakistan's interest has been to ensure continued access to water from these rivers. Around 90% of Pakistan's food and 65% of its population depend on agriculture around the Indus Basin. If, at any stage, this water was to be cut off or even reduced, the impacts on agriculture, human consumption, and water security in Pakistan would be catastrophic. The treaty was instrumental in granting assured water supply to Pakistan from the three rivers, and water security initially improved after the construction of water storage facilities as an outcome of the IWT. However, taking advantage of this provision, India initiated the construction of controversial water projects such as the Baglihar, Kishenganga dams, and Wooller Barrage, which undermine the spirit of the IWT. This appears to be an increasing manipulation of the provisions of the

IWT by India to cover its growing water and energy demands. The approach to water management, with a primary focus on dispute resolution under the IWT rather than cooperation, has challenged the overall water security of the region. The treaty does not provide a roadmap for both countries regarding actions to take during times of increased water demand. The growing water demand and scarce supplies have now made this a flashpoint for future conflicts between the two nuclear-armed riparians.

Impact On Flood Management

The treaty provided for Permanent Indus Water Commissioners for both sides to coordinate in respect of water levels in the Indus River system. As explained previously, information sharing on water flow levels takes place regularly, and this frequency increases during floods. With climate change, there is a need to review and recast this treaty in the light of cooperative water use and excess water management during floods. The recast treaty may provide for the diversion of excess flood water in the three western rivers toward Sutlej and Beas, which can be used for storage in Indian reservoirs on these rivers, and India may utilize it for its consumption. The reservoirs on the Indian side have enough capacity to store water deluges of up to 2010 flood levels. On average, these storages are filled up to around 50-55%, and even during the rain outburst of 2010, these reservoirs were filled up to 76% capacity (Irshad, 2022). India reported little or no damages in 2010 in comparison to the catastrophe that hit Pakistan. Similarly, during water-scarce months in Pakistan, water can be obtained from Indian reservoirs, on terms of mutual benefit. Water may be treated as a tradable commodity, and a ledger or water registry may be maintained to account for transboundary water movement.

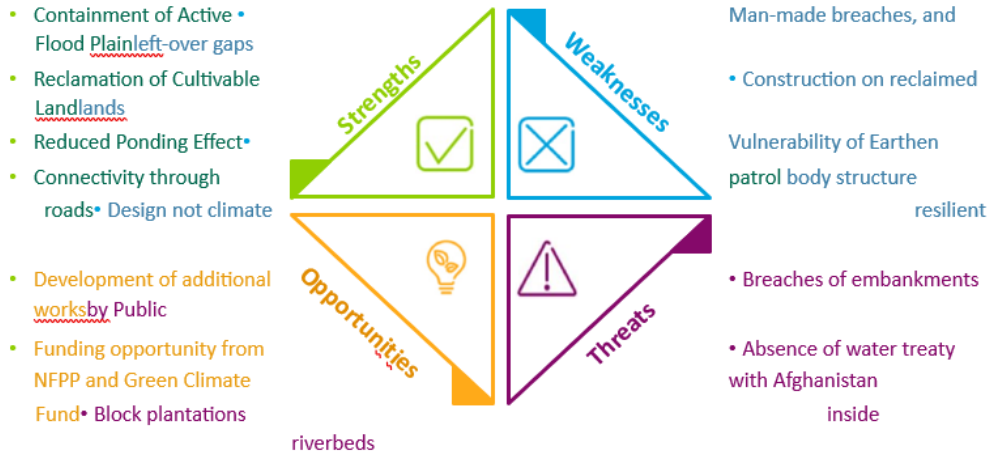
Dispute Resolution

From the perspective of humanitarian security and economic considerations, the Indus water basin is more crucial to Pakistan than to India. According to BATNA/WATNA Negotiation theory, a negotiated settlement is possible when there is an overlap between both parties' range of acceptable outcomes – i.e., the Zone of Possible Agreement (ZOPA). If the range of outcomes from both parties is large, it is easier to reach an agreement. However, in the current context, a major barrier to negotiations is the small range of possible outcomes acceptable to both parties. An effective negotiation strategy is to develop a larger range of possible outcomes by focusing on each party's interests and not positions and identifying an overlap in each party's ZOPA to advance negotiations.

To address mutual disputes, Article IX of the IWT talks about mechanisms to settle questions, differences, and disputes over hydro infrastructure projects.

Unfortunately, at many times, the provisions to resolve disputes have been used to halt the other's project. Successful negotiations will help establish a strong foundation for building a sustainable transboundary water management institution. The structural inflexibility of the Treaty does not encourage the riparian states to collaborate and build mutual trust for the common good. Instead of contemplating abrogation or finding faults with the IWT, both states can explore avenues for mutual benefits. Article VII of the Treaty talks about 'future cooperation' and conducting joint studies and engineering works to benefit the people living in the catchment area of the Indus, which has not been utilized to its full potential.

SWOT-EETH Analysis of Embankments Along Indus River



Strengths

1. **Containment of Active Flood Plain:** The embankment now defines the active flood plain, containing the river's spread and defining its boundary. It has played an instrumental role in reducing the spread and severity of flooding. The lower geographical spread and reduction in damage occurring in 2022 corroborate this strength of the embankment.
2. **Reclamation of Cultivable Land:** The construction of the embankment has reclaimed around 42,747 acres of cultivable land, enabling cropping on this reclaimed land.
3. **Reduced Ponding Effect:** Due to the construction of embankments on both sides, the floodwater does not get stagnant in the form of ponds – the "ponding effect." The presence of walls on both sides increases water velocity, thereby enabling quicker drainage of floodwaters.
4. **Connectivity through Patrol Roads:** Canal patrol roads are constructed atop wider portions of the embankment, thereby providing connectivity to the populations on the sides.

These strengths can be enhanced by building climate change-resilient embankments at the remaining vulnerable portions of the river. Furthermore, subsequent development funding may be utilized to raise the height of these embankments in light of the latest high water mark levels recorded.

Weaknesses

1. **Man-Made Breaches and Gaps:** Despite the construction of a lengthy embankment, gaps still exist, either due to land disputes or because of uncovered tributary openings. Moreover, man-made breaches by the local population also weaken the strength and effectiveness of this flood

protection infrastructure.

2. **Construction on Reclaimed Lands:** With the construction of the embankment, different structures have cropped up in the reclaimed land, in violation of river laws. This makes them susceptible to damage, even during moderate flooding.
3. **Vulnerability in High Floods:** This embankment is an earth-filled structure with stone pelleting on its face. With repeated flooding, the facing of the embankment is vulnerable to damage, which may expose the underlying earthen body.
4. **Non-Incorporation of Climate Change Resilience in Existing Design:** This embankment was planned and constructed soon after the 2010 floods, and at that time, the elements of disaster resilience were not incorporated into the design. Vulnerability due to rapidly changing climatic conditions has increased since then.

These weaknesses can be eliminated through a mix of legal and administrative measures. Legal measures to prevent construction in active flood plains and reclaimed lands include restoring the institution of canal magistrates and enforcing river laws using mechanisms provided in the removal of encroachment legislation. Administrative measures include improving the designs of embankments by incorporating elements of climate change resilience.

Opportunities

1. **Development of Additional Works:** There is an opportunity to construct additional works of 58 km, raising the height of the existing wall up to 24 feet, and strengthening the embankment to make it adaptable to climate change.
2. **Funding Opportunity from NFPP and Green Climate Fund:** There is now an increased focus on the water sector and flood mitigation. The 4th NFPP provides an opportunity to access funding for additional associated works on this embankment. Similarly, with increased donor interest, there is an opportunity to access resources from the funding pipeline of the $100 billion global Green Climate Fund.

The pipeline of projects to be proposed for funding under the $100 billion global Green Climate Fund is expected to open for Pakistan in 2024. For this purpose, the Asian Development Bank and United Nations Development Programme are assisting governments in developing sound project proposals to secure maximum funding. We need to take advantage of this opportunity and dedicate departmental wisdom to the task to secure maximum grant financing for Pakistan.

Threats

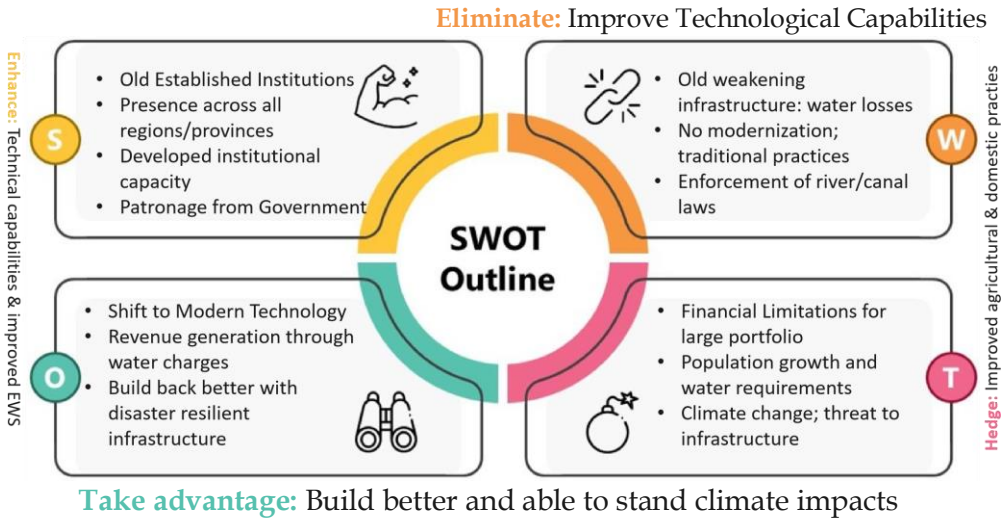
1. **Breaches of Embankment by the Public:** The local population tends to breach the embankment to address their local issues, such as accessing grazing areas or cattle movement. Any small gap is likely to provide an

opening for water to flow into adjacent lands.

2. **Absence of a Water Treaty with Afghanistan:** Unlike with India, there is no water accord or transboundary water treaty with Afghanistan. Any deluge in the River Kabul cannot be effectively addressed without coordination with Afghanistan.
3. **Block Plantations Inside Riverbed:** Recently, there has been an increased focus on block plantations in and around riverbeds, where public land and an easy supply of water are available. These plantations constrict water flow, thereby increasing the chances of water spilling over the embankment.

The threats can be mitigated by modifying national and provincial tree plantation programs to avoid block plantations inside active flood plains. Instead, linear plantations along riverbanks should be encouraged. This will result in the dual benefit of stabilizing the reclaimed land and embankments, while developing a natural barrier to prevent water from spilling over into adjacent settlements.

SWOT-EETH Analysis Of Provincial Irrigation Deptts



Strengths

1. **Old Established Organizations:** Almost all the provincial irrigation departments (PIDs) are long-established, pre-partition organizations with strong legal foundations. These organizations have established systems, practices, and organizational cultures, which enable them to execute large water sector infrastructure projects successfully.
2. **Countrywide Presence:** All federating units have functioning departments of hydrology and irrigation. These departments provide province-wide geographic coverage of most water bodies, a presence of

irrigation staff and outposts for information gathering and regulation, and other infrastructure for water management.

3. **Developed Institutional Capacity:** As long-established organizations, PIDs have developed their institutional capacity over time. Most of the organizations are well-resourced with qualified personnel and physical assets. These departments have long institutional memory, archived repositories of historical records dating back up to 100 years, and institutional practices are deeply ingrained in their organizational culture.
4. **Patronage from Governments:** Irrigation departments usually receive priority in the allocation of development funds. In KP, the allocated share for the water sector was 8% in the 2021-22 ADP (Rs. 16.5 billion) and 16% of the 2021-22 PSDP (Rs. 90.5 billion). Furthermore, irrigation, being indispensable for agriculture and human consumption, often receives strong support from legislators and governments, ensuring ownership of irrigation department projects and issues.

The strengths of PIDs can be enhanced by leveraging government patronage to augment their technical capabilities through a complete and gradual transformation from manual data collection practices to digital early warning systems. In addition to developing new structures, an adequate share of development funding should be allocated toward the continual maintenance and strengthening of older existing infrastructure.

Weaknesses

1. **Old Weakening Infrastructure:** Much of Pakistan's irrigation infrastructure has exceeded its useful life and is weakening after enduring repeated flooding over decades. Additionally, due to canal breaches, silting of dams and barrages, and weak enforcement capabilities of PIDs, inefficiencies have crept into the distribution network, reducing its storage and diversion capacity. This limits its ability to control flood deluges.
2. **Slow Pace of Modernization:** PIDs are still employing traditional practices for water management. Hydrology data is still being collected by human gauge readers at 137 gauge-reading stations and communicated using ad-hoc telecommunication methods, without any real-time radio network. This affects the reliability of data, which is prone to human error. Most canal closures and diversions are manually operated, and major canals are unlined, resulting in water losses of up to 50%.
3. **Enforcement of Water Laws:** Since the abolition of canal magistracy, the

enforcement of water laws, primarily the Rivers Ordinance of 2002 and the Canal & Drainage Act of 1873, has weakened. Encroachments have cropped up in river basins, and water bodies are being constricted, especially in mountainous areas.

The existing weaknesses of PIDs can be addressed by embracing technology. Procurement of modern digital equipment and software systems for asset management, process re-engineering, and data collation, as planned under the 4th NFPP, is a step in this direction. The restoration of the institution of canal magistracy will empower PIDs to enforce canal and drainage laws and prevent encroachments.

Opportunities

1. **Shift to Modern Technologies:** With increasing water requirements due to population growth, there is an ever-growing need to improve the efficiency of the water distribution network. This can be achieved through the adoption of modern technologies, such as replacing manual gauge readers with telemetry-based Early Warning Systems (EWS), and gradually replacing old manual canal gates with hydraulic electro-mechanical gates.
2. **Revenue Generation through Water Charges:** Currently, most operational and developmental expenditure on the water sector is funded through public sources, with very little revenue generation from internal sources. The FoDP has recommended increasing the current rate of Rs. 120/acre to at least Rs. 1500/acre. This would generate an annual revenue of Rs. 60 billion, which can be used for the rehabilitation and improvement of irrigation infrastructure without burdening public budgets. Other avenues, such as a cess on sand excavation and commercial activities around rivers, could also generate additional revenue.
3. **Build Back Better Damaged Infrastructure:** Recent floods have caused widespread damage to water infrastructure, estimated at Rs. 168 billion across the country. This presents an opportunity to rebuild the damaged and dilapidated infrastructure using new, disaster-resilient designs that incorporate climate adaptation elements.

While flood disasters have debilitating impacts on irrigation infrastructure, PIDs can take advantage of this opportunity to rebuild damaged structures with resilience in mind. Furthermore, the entire flood protection regime is currently funded through public resources, which presents an opportunity to treat water as a service and commodity, charging service fees to help fund these works.

Threats

1. **Financial Limitations for a Large Portfolio:** The need to rebuild the damaged infrastructure across the country stands at a staggering Rs. 168 billion (PDNA, 2022). Furthermore, according to the 4th NFPP, an additional investment of Rs. 178 billion is required to execute the proposed flood protection works and non-structural measures. Fiscal resources are finite, and without a workable revenue generation plan, it will be difficult to meet such costs through public sector funding alone.
2. **Population Growth and Increasing Water Requirements:** With an ever-increasing population, water requirements are rising, while water availability per capita is simultaneously decreasing. This will place enormous stress on the available water resources and the irrigation infrastructure. PIDs need to collaborate with agriculture departments to introduce modern water-conserving techniques such as drip irrigation, land leveling, rainwater harvesting, and watercourse lining.
3. **Climate Change and Threat to Infrastructure:** Climate change is a real and growing threat, likely to trigger floods with increasing frequency and intensity. The weak and dilapidated irrigation infrastructure is at increased risk, as it is the primary structure exposed to flood deluges.

The looming threat of water scarcity can be mitigated by introducing modern agricultural practices, such as drip irrigation, land leveling, and watercourse lining, while improving water consumption habits among the population. Responsibility toward the environment and the sustainable use of natural resources must be the foremost strategy to counteract the impacts of climate change.

Gap Analysis

Based on our study and the analysis of institutions, flood protection works, and coordination mechanisms, a gap analysis has been conducted across four dimensions: organizations, direction, process, distribution and spread, and technology:

Area under Consideration	Organizations involved in management of water flows	
Specific Area under Consideration	Coordination mechanism between federal, provincial and district level government agencies towards management of water flows generally and during floods	
Desired State	**Current State**	**Action Steps**
- FFC to be the lead coordinating agency for management of floods countrywide - All agencies incl. IRSA, NDMA, and WAPDA to operate under the supervisory umbrella of FFC during flood season - Broad based composition of FFC, represented by all provinces, relevant organizations, and headed by Federal Minister for Water	- Multiple agencies with scattered responsibilities and overlapping of functions - FFC only with a passive role in flood management: digression from stated role - RMCs with ultimate decisionmaking authority to control water discharge at reservoirs - Collection/Compilation of hydrology and rainfall data fragmented amongst four levels of organizations - Sharing of minimal required information on water levels by India through PIWC.	- Legislation to effect the changes in composition, and role of FFC - Updation of guidelines/SOPs of RMCs - Mass community awareness drives for populations residing close to active flood plains. Rs. 30 million allocation in 4th NFPP for flood related workshops. - Development of integrated software system for sharing of real time information amongst agencies - Rs. 1.3 billion allocations under 4th NFPP for capacity building of institutions engaged in flood management - Rs. 50 million allocation for training

Resources - Integrated data management from all provincial irrigation deptts, and EWS of WAPDA, PMD, and PIWC		of computer staff of PIDs, WAPDA

Area under Consideration	Business Process: Geographic distribution and effectiveness of flood protection works	
Specific Area under Consideration	Embankments in the Indus River System, including Kabul and Swat Rivers, their spread, need, and their role in minimizing damages to human settlements	
Desired State	**Current State**	**Action Steps**
- Planned construction of embankments and other flood protection works to cover other vulnerable areas	- 6,820 km of embankments built around major rivers in Pakistan - 352 km of embankments in KP	- Construction of 582 schemes worth Rs. 91 billion proposed under 4th NFPP - Construction of flood management structures across hill torrents costing
- Extension of Nowshera embankment by further 58 km, totalling 163 km - Standardized disaster resilient designs for embankments - Flood valve gates at all 23 tributaries falling into main rivers	- Arbitrary determined height of 6 feet above high water marks - Varying designs and strengths, owing to construction over different periods of time - Existing length of Nowshera embankment = 105 km - 3 flood valve gates installed.	- Rs. 26.3 billion under 4th NFPP - Wall raising from existing 20 feet to 24 feet. - Strengthening of existing embankment through climate resilient design. Project planned for *Rs. 14 billion*. In first phase, water carrying capacity to be increased till 320,000 cusecs

Increased water carrying capacity of river Kabul from present 281,000 cusecs to 350,000 cusecs		- Project worth Rs. 71 million for installation of 20 remaining gates

Area under Consideration	Business direction of Indus Water Treaty	
Specific Area under Consideration	Indus Water Treaty, and its impacts on water security and flood management for both riparians, and establishing similar arrangements with Afghanistan	
Desired State	**Current State**	**Action Steps**

- Cooperation between India and Pakistan on water flow management, preventing adverse impacts on communities from both sides - Conservation and development of water resource in Indus River Basin. - Fighting the effects of Climate Change - Dependable and transparent dispute resolution mechanism	- The treaty approaches water management through the lens of dispute prevention and resolution than mutual collaboration - Adversarial rather than supportive relationship between riparians - Water Security of both states under stress - Weak enforcement mechanism, and moderately strong dispute resolution mechanism	- IWT to be reviewed, renegotiated, and recast between riparians - Third part assessment of demands and capacities on sides of the border - Joint monitoring, forecasting, and collaborative early warning system by sharing rainfall data at catchment areas, weather prediction for mutual benefit - Access to barrage/reservoir level, and periodic seasonal visits of Indus Commissioners - Setting up of Water Registry/Ledger and nominating a neutral guarantor - As a first step, commencement of
		negotiations with Afghan government for sharing of hydrology information. - Mutually agree on environmental protection measures, and water conservation approaches

Area under Consideration	Technology employed in Early Warning Systems
Specific Area under Consideration	Deployment of technology-based solutions for collection of hydrology data, weather information and its dissemination in real time

Desired State	Current State	Action Steps
- Country wide coverage of digital telemetry based real time Early Warning System - Accurate prediction of floods - Unified data compilation and issuance of flood advisories	- Old radars, and manual data collection systems - Hydrology data collection partially through manual gauge stations, and partially through telemetry systems - Incompatibility between different systems - Data collected/compiled from multiple sources and organizations - Current density of observatories lower than WMO standards	- Upgradation of existing radars of PMD - Installation of 27 no telemetric rain gauges - Establishment of four more flood early warning centers. - Improvement of density by installation of 39 no. radio sounding stations. - Cost allocation of Rs. 4.2 bn made in 4th NFPP - Inclusion of catchment area upstream Tarbela dam. - Rs. 300 mn reserved for metrological studies

Conclusion

Recurring floods in Pakistan have debilitating impacts on the economy and the lives of its people, which over time have necessitated the presence of specialized institutions to manage various aspects of flood management. These institutions actively coordinate on these aspects, particularly regarding water flow management, and the collection and sharing of information for flood forecasting. We observe that there is overlap in the mandates and practices of these institutions, along with the generation of multiple advisories and predictions by them. It is also observed that information is gathered by many institutions simultaneously through multiple and often

mutually incompatible methods, ranging from manual gauge reading to digital telemetry solutions. This renders these forecasts susceptible to inaccuracies and delays.

Additionally, both federal and provincial governments have made significant investments in flood protection infrastructure; however, there is still a vast need for further investments in vulnerable areas. Climate change has further accentuated this need. These investments have yielded positive returns in terms of minimizing both human and material losses. The embankment around the River Kabul, in particular, has surpassed value-for-money calculations in its first operational test during the 2022 floods. Finally, we note that the Indus Water Treaty, concluded nearly six decades ago, initially improved the water security of the country. However, due to the ever-increasing demand for water against dwindling supplies, and the treaty's limited scope of viewing water distribution solely from the lens of dispute resolution, the treaty in its present form has outlived its utility, necessitating its revision to improve water security and flood management for both riparians.

Recommendations

In pursuance of the Pareto Principle, the following recommendations are offered to address key issues identified through different analyses carried out above, along with their Logical Framework Matrices:

1. To reduce the overlap between the mandates of different organizations coordinating on the control of water flows during the flood season, it is proposed that decision-making on this aspect be integrated at the Federal Flood Commission (FFC), giving it the role of the lead agency during floods, in contrast to the existing fragmentation.
2. Explore alternative methods of water management during floods. The current focus is on building walls against water flow. An alternative could be channeling this excess water through barrages and outfall drains.
3. As we have witnessed, extreme weather conditions, specifically flooding, in Pakistan are becoming a recurring phenomenon. To adapt and mitigate such events, we need to invest in climate-resilient infrastructure. Currently, we have constructed 6,820 km of flood embankments along the entire Indus River Basin with varying designs and specifications. The 4th NFPP provides an implementation plan to strengthen the current embankments and further develop flood protection infrastructure. Given the emergent needs for flood mitigation, federal and provincial governments need to allocate at least 10% of their development portfolio for the cause, as recommended by the National Water Policy of 2018.

4. Arbitrations on the Kishanganga project in India recommended the appointment of a neutral expert to assess the design flaws. Pakistan has so far resisted this suggestion and vows to approach the International Court of Justice against the arbitration. However, the suggestion of a neutral expert should be accepted, as any other adjudicating forum is likely to issue findings before deciding on our petition.
5. As previously highlighted, the Indus Water Treaty needs to be recast into an agreement for cooperation between Pakistan and India on the issues of climate change and addressing growing water scarcity. Viewing the IWT through the lens of dispute resolution has rendered the treaty only partially effective in the wake of growing challenges.
6. There is a need to develop an integrated Early Warning System (EWS), with geographic density as per World Meteorological Standards (WMO), as recognized by the FFC in its 4th NFPP. At present, multiple agencies collecting identical data result in inaccuracies and delays. The proposed system should rely on interoperable telemetry tools, feeding data in real time onto an internet-enabled portal that can be accessed by all stakeholders. A relevant example to emulate is the Flood Damage Assessment Portal established by the Performance Management & Reforms Unit in Peshawar.
7. At present, there is resistance to charging water fees from consumers, and political will is lacking. The entire irrigation and flood protection infrastructure is developed and maintained through only public funds or international loans. Water needs to be treated like any other service and commodity (such as electricity or gas) and should be adequately charged to recover some of the operational costs and bring sustainability to the investment plan. The FoDP suggests that Rs. 60 billion in revenue could be generated alone by revising the water rate to Rs. 1,500 per acre per year, up from the existing Rs. 120 per acre. The total portfolio recommended for construction in the 4th NFPP is Rs. 194 billion, which could be met from the revenues of just three years.

Problem: Lack of coherent coordination among agencies responsible for water flow management					
Risks and Assumptions	**Input**	**Activities**	**Outputs**	**Outcomes**	**Impact**
Political power dynamics can compromise consensus Multiple agencies with scattered responsibilities and overlapping of functions FFC only with a passive role in flood management: digression from stated role	Political capital and will Training of Staff Research study to optimize the coordination model	Legislation to effect the changes in composition, and role of FFC Updating of guidelines/SOPs of RMCs Development of online data portal linking up relevant agencies	All agencies incl. IRSA, NDMA, and WAPDA to operate under the supervisory umbrella of FFC during flood season Broad based composition of FFC, represented by all provinces and relevant organizations, to be headed by Federal Minister for Water Resources Integrated data management from all public agencies	Improved Coordination mechanism between federal, provincial and district level government agencies for water flow management Unit of command to decide on water flow management	Timely decision making enabling reduction in debilitating impacts of floods

Problem: Minimal water charges on domestic usage and agriculture					
Risks and Assumptions	**Input**	**Activities**	**Outputs**	**Outcomes**	**Impact**
No political will Lack of robust collection mechanisms for water charges (*abianas*) Resistance by the public and farmers	Political will and capital Stakeholder management Mapping of water users digitially	Revision of necessary legislation and government policies Metering of water like electricity and gas in large cities Introduction of new water rates for irrigations	Generation of sustainable revenues through water charges	Incentivize to conserve water Improved public investment in flood protection through revenue generations	Creating of a cycle of sustainable public investment and revenue generation leading to better adaptation and mitigation of floods

Problem: Lack of proper utilization of Indus Water Treaty for cross-border coordination in event of floods and addressing water security of the region					
Risks and Assumptions	**Input**	**Activities**	**Outputs**	**Outcomes**	**Impact**
Politically sensitive negotiations Agreements subject to mutual consensus and international guarantors External factors like wars and terrorism can derail cooperation Lack of trust between countries	Political will and capital Technical Human Resources Stakeholder Management Negotiation	Take up the pending disputes as per India's request to Neutral Expert for decisions Discussion to revisit the treaty between the two commissioners	Implementation of Kishenganga Decision in 2013 Process of appointment of neutral expert begins A recast treaty with elements of addressing water scarcity and effects of climate change.	Improved crossborder water management Cooperation to address issues of water excess during flood season, and water scarcity in dry season	Improved water security for Pakistan allowing for better utilization of water and related information through the cooperation

Problem: Incompatibility of water related data between different entities and lack of integrated usage of technology to gather data on water levels					
Risks and Assumptions	**Input**	**Activities**	**Outputs**	**Outcomes**	**Impact**
Asymmetric uptake and understanding of technological solutions; Hydrology data collection partially through manual, and partially through telemetry systems Old radars Traditional methods of data collection by PID makes data unreliable	Political will and capital Financial Resources. Allocation of Rs. 4.2 bn for equipment in 4th NFPP Rs. 300 mn for metrological studies Stakeholder management Trainings	Upgradation of existing radars of PMD Installation of 27 no telemetric rain gauges Establishment of four additional flood early warning centres Installation of 39 no. radio sounding stations Inclusion of catchment area upstream Tarbela dam	Accurate forecasting through upgraded radar systems Improved rain and water flow measurements Accurate and timely early warnings Improvement of density of weather stations increasing the accuracy of weather models	Improved technological solutions for realtime collection and dissemination of data on hydrology and weather, enabling lead time to disaster response agenices	Better response and coordination in managing the disaster

Problem: Development of climate resilient flood protection Infrastructure to manage flooding impacts					
Risks and Assumptions	**Input**	**Activities**	**Outputs**	**Outcomes**	**Impact**
Availability of fiscal resources Existing embankments could be weak & would necessitate reconstruction Breaches of embankments by local public Continued encroachments in river basins, and water bodies	Financial Resources (Rs. 194 bn, PSDP) (Rs. 14 Bn, ADP) Rs. 71 Mn for Flood gates Technical Human resources Planning Capabilities	Construction of 582 schemes proposed under 4th NFPP Construction of flood management structures across hill torrents under 4th NFPP Strengthening of existing embankments through climate resilient design Installation of 20 remaining flood valve gates	Flood embankments at additional 58 Km around Kabul River Flood management structures across hill torrents worth Rs. 26.3 Bn Robust and climate resilient embankments Increased water carrying capacity till 320,000 cusecs	Strengthened embankments on the Indus River System, including Kabul and Swat Rivers, as a flood protection measure	Better protection from devastating impacts of floods, saving previous lives, crops and public infrastructure

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