The People's Republic of China

Islamic Republic of Pakistan

Investigation and Advisory Report on 2022 Catastrophic Floods in Pakistan

Chinese Governmental Flood Control Expert Group

November 2022

CamScanner

Foreword

Since June 2022, Pakistan has been affected by extreme monsoon rainfalls, causing catastrophic floods in many parts of the country and heavy casualties and property losses. The Pakistani government declared a state of national emergency and appealed to the international community for assistance. Chinese President Xi Jinping and Premier Li Keqiang extended condolences to the Pakistani President and Prime Minister respectively, while the Chinese government responded immediately and provided a large amount of emergency relief materials and financial assistance to Pakistan to support its flood relief and post-disaster rehabilitation work.

Under the coordination arrangement of the Ministry of Foreign Affairs, China and the China International Development Cooperation Agency, the Ministry of Emergency Management took the lead, together with the Ministry of Water Resources and the China Meteorological Administration, in the establishment of a Chinese Governmental Flood Control Expert Group (hereinafter referred to as the "Chinese Expert Group"; expert names listed in appendix). The Chinese Expert Group is composed of senior experts in meteorology, hydrology, flood control planning, flood management, emergency response, disaster relief and rehabilitation, etc. From October 11 to 21, 2022, the Chinese Expert Group went to Pakistan to carry out on-site disaster investigations and consulting services on flood control and disaster risk reduction (DRR). This is a concrete practice of China and Pakistan in jointly building a community of shared future for mankind and jointly fighting against major natural disasters. Before the trip, the Chinese Expert Group had established support mechanisms from domestic dispatching institutions in China, submitted a list of data requests to Pakistan in advance, and suggested that Pakistan could put forward its counterpart experts in different fields to work with the Chinese Expert Group.

During its stay in Pakistan, the Chinese Expert Group carried out many discussions and exchanges with officials and experts from the National Flood Response and Coordination Committee (NFRCC), the National Disaster Management Authority (NDMA), the Federal Flood Commission (FFC), the Pakistan Meteorological Department (PMD), the Space and Upper Atmosphere Research Commission (SUPARCO), and Water and Power Development Authority (WAPDA). The Chinese Expert Group conducted on-site investigations in the worst-hit areas of Dadu City and Mirpur Khas City of Sindh Province, and investigated the Tarbela Dam. On the basis of conscientious analysis and study, the Chinese Expert Group hereby puts forward the *Investigation and Advisory Report on 2022 Catastrophic Floods in Pakistan*.

CamScanner

The Chinese Expert Group was powerfully supported and closely cooperated by Pakistan's NFRCC, NDMA, FFC, PMD, SUPARCO, WAPDA as well as officials and experts from Sindh Province and relevant local governments. The Chinese Expert Group would like to express its gratitude together with sincere admiration and respect to the dedication and high level of professionalism displayed by federal, provincial and territorial government officials and experts.

Due to time constraints, the Chinese Expert Group only investigated limited areas in the lower reaches of the Indus River, and confronted difficulties in collecting the complete data requested. The group also did not have an in-depth understanding of the law of flood occurrence, or the flood control and DRR system in the Indus River Basin. In addition, the national conditions, flow regimes and management modes of China and Pakistan are different, making inappropriacy and omissions in the advisory opinions inevitable and leaving some issues worth further study. The Chinese Expert Group sincerely hopes that the consultation outcomes can provide useful help to Pakistan's flood control and disaster mitigation activities, and make due contributions to deepening the all-weather strategic partnership and friendship between China and Pakistan.

CamScanner

Contents

CamScanner

1 Basic Situations

1.1 Overview of water system

About three-fifths of Pakistani territory is mountainous and hilly, which can be divided into three main geographical areas, namely, the Northern Highlands, the Indus Plain and the Baluchistan Plateau.

The main river system is the Indus River basin, which originates from the Sengge Tsangpo (Shiquan River) in China in the western Himalayas, passes through the Himalayas and the Karakoram Mountains, enters the Pakistan-controlled Kashmir region about 120 kilometers upstream of Skadu City, then flows through the Grand Canyon section from Skadu to Bangi, attracts the Gilgit River near Bangi, and turns southwest throughout entire Pakistan. Finally, it flows into the Arabian Sea, with a total catchment of 1.034 million km^2.

The Indus River System has many tributaries that join the river in the course of its flow. The major tributaries on the left bank are Jhelum River, Chenab River, Ravi River and Sutlej River. The major tributaries on the right bank are Shyok River, Gilgit River, Kabul River and Gomal River (Fig. 1).

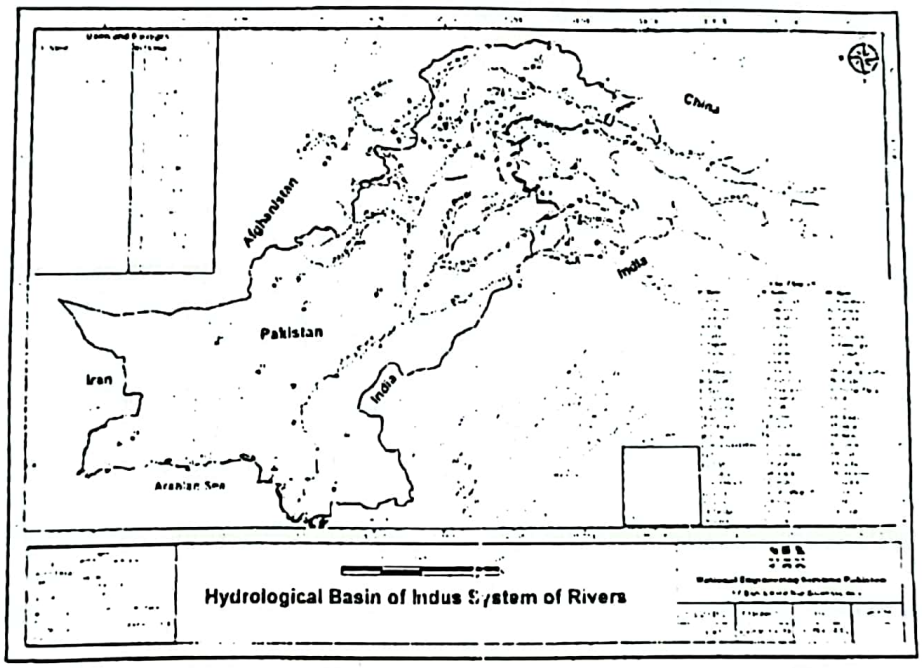


Fig. 1 The Indus River system map (Source: the Ministry of Water Resources, Pakistan)

The mainstream of Indus River is divided into three sections: upstream, downstream and estuary. The upstream section from the source to Kalabagh is about 1,370 km, with narrow river course, steep gradient, many rapids and high current velocity. The downstream section is from Kalabagh to Hyderabad, with a length of about 1,200 km with riverbed elevation between 20 and 200 meters, low gradient, wide river course, multi-threaded channels and slow flow velocity. Below Hyderabad is the estuary reach, i.e. the Indus Delta, with a main channel length of about 260 km.

1.2 Meteorology and hydrology

Pakistan is located in the subtropical zone. With exception of the Baluchistan area, most of Pakistan territory lies on tropical monsoon climate regions. The period from December to March of the next year is the northeast monsoon season, with low temperature, few precipitation and low humidity; the period from April to June is the transition period from the northeast monsoon to the southwest monsoon, with dry air and high temperature; the period from July to September is the southwest monsoon season, with more rainfall, more thunderstorms and high humidity, which is the rainfall season of the whole year; and the period from October to November is the transition season from the southwest monsoon to the northeast monsoon, with large temperature difference between day and night and few precipitation.

The spatial distribution of annual precipitation in Pakistan average from 1981 to 2010 is uneven, showing a pattern of less-more-less from north to south. The annual precipitation in high mountains in the northwest is generally less than 200 mm; the annual precipitation in northern Khyber Pakhtunkhwa, northwestern Punjab and western Jammu and Kashmir is more at about 1,000-1,600 mm, and locally over 1,600 mm; precipitation is generally 100-250 mm in the south, 50-100 mm in the southwest, and less than 50 mm locally (Fig. 2). Yearly precipitation varies widely, and alternating flood and drought years are common. The main types of flood disasters include riverine floods, flash flood, urban floods, pluvial floods and glacial lake outburst floods (GLOF).

CamScanner

The mountainous region of the upper Indus receives precipitation largely in the form of snow. Most of the runoff of the Indus River is fed by melting snow and glaciers from the Karakoram, Hindu Kush and Himalayas, and the rest fed by monsoon rains (July-September).

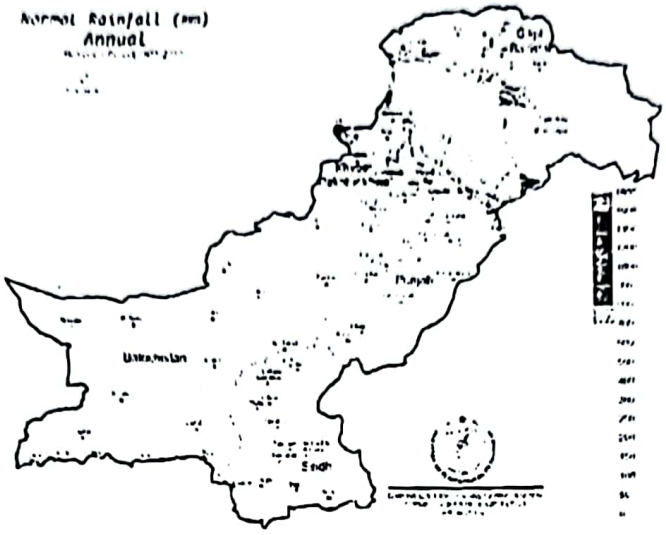


Fig. 2 Distribution diagram of annual precipitation in Pakistan (1981- 2010 average)

1.3 Flood Control and Disaster Risk Reduction (DRR) System

1.3.1 Structural Flood Control Measures

At present, Pakistan has initially established a flood control engineering system in the Indus River Basin that mainly composed of reservoirs, dikes, revetments and spur dikes, as well as irrigation system and a partial drainage system mainly covering downstream plain areas.

(1) Reservoir. There are a small number of reservoirs in the upper reaches of the Indus River, including Tarbela on the mainstream of the Indus River, Mangla on the Jhelum River and Wasak on the Kabul River, which are mainly used for irrigation and power generation.

(2) Dikes and spur dikes. Dikes with a total length of about 6,820 km have been constructed along the mainstream of the Indus River and its major tributaries, mainly in the provinces of Punjab, Sindh and Balochistan. In addition, 1,410 spur dikes were built to avoid land erosion caused by changes in river morphology.

CamScanner

(3) Revetments. In order to prevent riverbank collapse caused by the lateral erosion and scouring of the river channel, some riverbank protection works have been built on both sides of the Indus River and its major tributaries, especially in the hilly areas with high flow velocity, and the main structure type is gabion net retaining wall.

(4) Irrigation system. The water diversion and irrigation system of the mainstream of the Indus River and its major tributaries is quite perfect. Most of them rely on the construction of barrages such as Guddu, Sukkur and Kotri to divert water into the main canal and then to the farmland by gravity through the irrigation water distribution system.

(5) Drainage system. The lower reaches of the Indus River are mostly arid or semi-arid areas, and the construction of drainage facilities lags behind and has deficiency. The drainage facilities in Sindh Province are mainly composed of drainage canal systems.

1.3.2 Non-Structural measures

(1) Monitoring data and services. There are about 100 surface meteorological ground observation stations in Pakistan (Fig. 3), including 35 stations in mountainous areas and the rest in plain areas. There are 7 weather radars, mainly distributed in the east and northwest regions. Satellite receiving ground stations have been established in Islamabad, Karachi and other places to receive data from polar orbit satellites and geosynchronous orbit satellites. Some hydrological stations have been established in the mainstream and major tributaries of the Indus River, including 9 controlling stations on the mainstream, and the monitoring data include water level, discharge and sediment, etc.

CamScanner

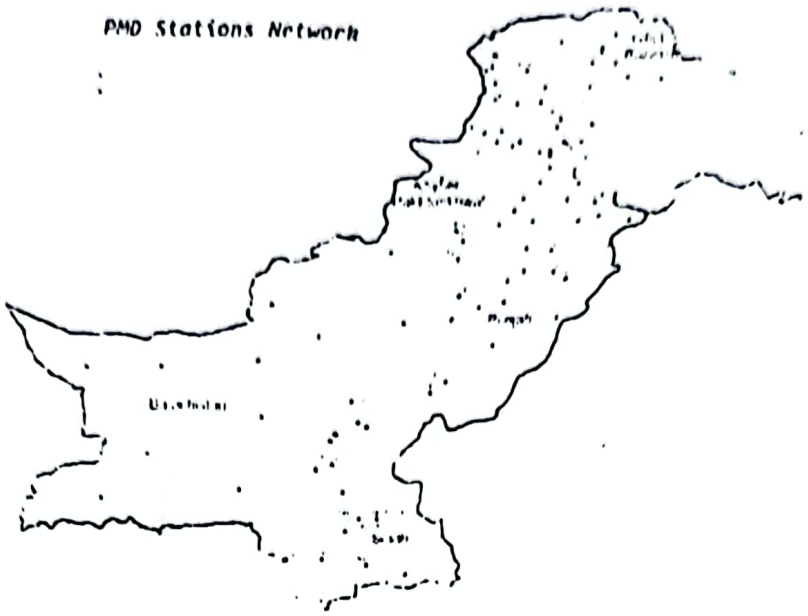


Fig. 3 Distribution diagram of monitoring stations

Meteorological and flood operational services mainly include climate prediction and weather forecasting, hydrometeorological services and flood forecasting, providing weather forecasting services as well as early warning of tropical cyclones, rainstorms, floods and other disasters to government departments and the public in forms of electronic documents, written reports and news media. A short-term, medium-term and long-term weather and climate forecast system has been established.

(2) Policies and plannings. Pakistan has formulated a series of flood management policies and plannings, including the *National Water Policy 2018*, *National Water Policy Implementation Framework*, *National Flood Telemetry Network Stations Master Planning*, *National Flood Control Planning IV*, *Study on Countermeasures for Discharging Downstream of the Kotri Barrage to Prevent Seawater Intrusion 2005*, *General Report on Feasibility Study of Flash Flood Management in Pakistan 1998*, etc. Some urban areas have

CamScanner

enacted laws to prevent encroachment in river floodplains.

(3) **Responsibility system.** The responsibility system for flood management in Pakistan is shown in Fig. 4. Stakeholders take actions according to their flood management assignments and duties. Among them, the PMD issues weather forecast information through daily bulletins, and the PMD and the FFC issue warnings or alerts. The responsibilities of various stakeholders are clearly defined in the *National Monsoon Contingency Plan*.

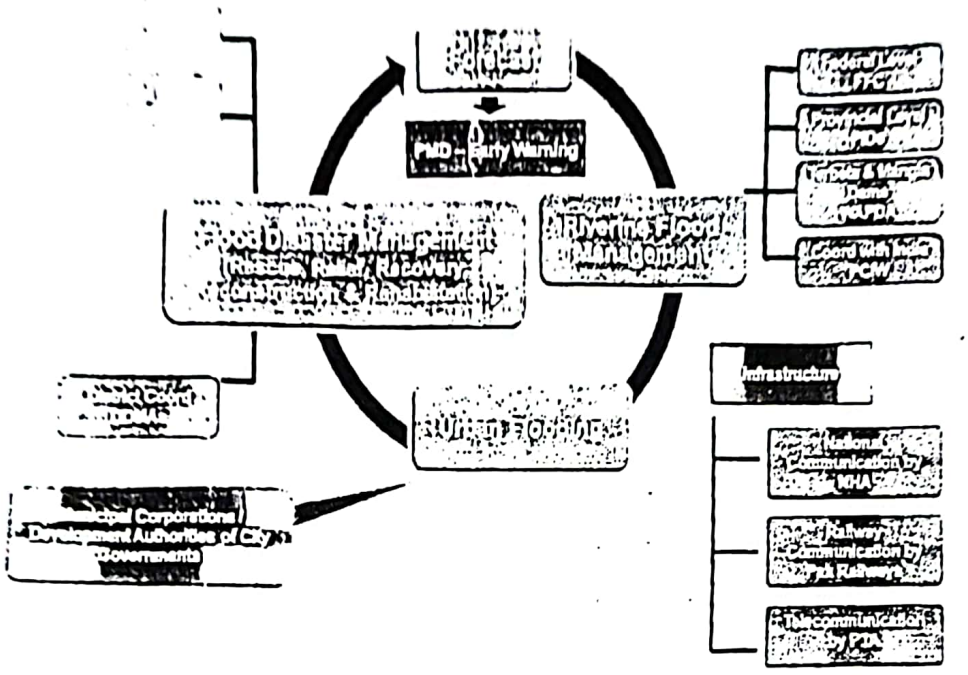


Fig. 4 Responsibility system for flood management

(4) **Flood risk maps.** Flood risk maps have been prepared along the Indus River and its major tributaries. Flood inundation range and water depths in a return period of 5 years to 50 years analyzed, and risk areas divided according to severity.

(5) **Monitoring, forecasting and early warning.** Weather and flood forecasting is carried out by the PMD and its affiliated Flood Forecasting Division respectively. Flood forecasting and early warning information is released through internet, SMS, fax, e-mail and mobile communication applications, as well as news media and public networks.

(6) **Reservoir regulation.** The main functions of the Tarbela Reservoir and the Mangla

Reservoir in the upper reaches of the Indus River are irrigation and power generation, with consideration on the incidental needs of flood control, thus the reservoirs are regulated according to the operation management manual and standard operating procedure.

1.3.3 Emergency management in Pakistan

(1) Commanding coordination and responsibilities of sectors

The National Disaster Management Council (NDMC), chaired by the Prime Minister, with the President of the NDMA as Secretary General, is the highest decision-making body in the field of Pakistani disaster management.

The NDMA is the executive arm of the NDMC, in charge of coordinating government ministries/departments/organizations, armed forces, international non-government organizations (INGOs), non-government organizations (NGOs) and UN agencies. It is responsible for full-cycle disaster management including disaster mitigation, preparedness, response, relief and recovery, as well as the development of the National Disaster Management Plan.

The main departments and institutions related to flood control and DRR in Pakistan include the Ministry of Water Resources, the FFC, the WAPDA, the Indus River System Authority, the PMD and its Flood Forecasting Division. Their specific responsibilities are as follows: (1) The Ministry of Water Resources is responsible for developing national water resources and hydropower resources, implementing national water policies, and liaising between Pakistan and the international water engineering organizations. (2) The FFC, which is subordinate to the Ministry of Water Resources of Pakistan, is responsible for the preparation, implementation assessment and review of the national flood control planning, and provides advisory services to the Ministry of Water Resources on engineering issues. (3) The WAPDA is responsible for the integrated rapid development and maintenance of the national hydropower resources, including the control of soil salinity and waterlogging. (4) The Indus River System Authority regulates and monitors the allocation of water resources in the Indus River in accordance with the water agreements among the provinces. (5) The PMD undertakes the national operations in the fields of meteorology and hydrology, and provides

CamScanner

services for public activities and projects requiring climate information. (6) The Flood Forecasting Division is a subordinate unit of the PMD, which is responsible for weather and flood forecasting and warning information issuance. (7) Provincial irrigation departments are responsible for the operation and maintenance of irrigation systems, as well as river surveys and hydrological data. (8) Provincial disaster management administrations are responsible for disaster preparedness, preparation of emergency plans, rescue and relief measures and recovery plans, examination of vulnerability to disasters and formulation of preventive measures, formulation of guidelines for disaster management plans, assessment of disaster preparedness, coordination of disaster response measures, organization and promotion of DRR knowledge popularization, risk avoidance awareness and community training.

(2) Plan development

Each year, all the federal and provincial disaster management stakeholders coordinate the development of a directive flood contingency plan based on the long-term weather forecasts and climate change analysis from the PMD. The contents of the plan mainly include flood management responsibilities, deficiencies of flood control projects, flood threats and vulnerabilities, monsoon response guidelines, drought response guidelines, and specific suggestions on key actions to be taken. According to the analysis and judgment results of water regime of the year, the WAPDA and irrigation departments formulate operating plans and emergency plans for reservoirs and irrigation canals.

(3) Emergency Response

Relevant standards, guidelines and plans for emergency response are formulated by the NDMA, and the specific implementation is undertaken by provincial rescue forces. Provincial Rescue Services 1122 are comprehensive rescue organizations. Provincial firefighters assist in rescue actions, with police and relevant government emergency personnel participating in rescue on demand. Once the disaster reaches certain level, the Pakistani armed forces participate in the emergency response at the request of the federal government. Many domestic non-governmental organizations participate in emergency response on request or on their own initiative, and relevant government departments will provide training services for

citizens as first responders.

(4) Disaster relief management

In the event of a natural disaster, all stakeholders, including government ministries departments/organizations, armed forces, INGOs, NGOs and UN agencies, are organized by the NDMA[1] to work in a unified manner (Fig. 5).

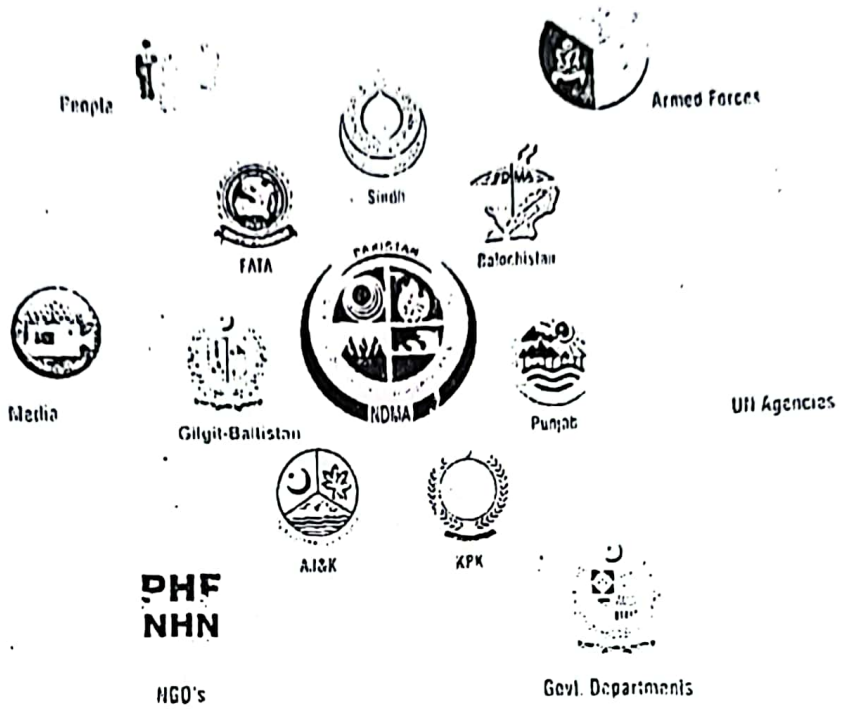


Fig. 5 Diagram of disaster relief management structure

(5) Flood control and DRR legislation

The *National Disaster Management Act 2010* requires the establishment of disaster management committees at the federal and provincial levels and disaster management departments at the federal, provincial and prefectural levels to formulate national, provincial and prefectural disaster management plans. In 2018, the Ministry of Water Resources formulated and issued the *National Water Policy*, under which each province formulated its own sustainable development planning for water resources. Provincial governments undertake

[1] http://cms.ndma.gov.pk/

river management, irrigation and agriculture, rural and urban water supply, environmental and other water-related functions. Punjab and Khyber Pakhtunkhwa have passed the *Provincial River Act*, as the *Federal River Act* is moving forward.

1.4 Historical flood disasters

Since its independence, Pakistan has suffered from many big floods in 1950, 1955, 1956, 1959, 1973, 1976, 1978, 1988, 1992, 1994, 1995, 2010 and 2011, causing casualties and huge economic losses to varying degrees. Some of the most severe floods include the following:

(1) 1955 Floods. The floods mainly came from the Ravi River, a tributary of the Indus River, with peak discharge of 630 thousand cubic feet per second (hereinafter referred to as cusecs) at Madhopur headwork and 542 thousand cusecs at Balloki headwork. It breached the flood dikes of the Bambanwala-Ravi-Bedian-Dipalpur Link Canal, and the levee of Lahore suburbs. The direct economic losses were about 380 million US dollars.

(2) 1973 Floods. The floods mainly came from the Kinab River, a tributary of the Indus River, with peak discharge of 1 million cusec at Khanki Headworks and 802 thousand cusecs at the Panjnad Barrage, inundating 3.6 million hectares of arable land and destroying crops such as wheat and cotton. Punjab lost 70,000 cattle and 255,000 houses, and 474 people died. The direct economic losses were about 5.13 billion US dollars.

(3) 1976 Floods. The rainfall in the Indus River Basin from July to September was 579 mm, and the and the peak discharge was 862 thousand cusecs at Jinnah Barrage, and 1.19 million cusecs at Guddu Barrage. Due to inundation and flood, 425 people died, 1.7 million people in 18,390 villages were affected, 8 million hectares of land were inundated, and 11,000 houses were damaged. The direct economic losses were about 3.49 billion US dollars.

(4) 1992 Floods. Extensive heavy rainfalls occurred in the Indus, Jhelum and Kinab Rivers. The Rasul Barrage on the Jhelum River had a peak discharge of 987 thousand cusecs. 4.8 million people were affected, more than 1,000 people died, 13,000 villages were flooded and 960,000 houses were destroyed. The direct economic losses were about 3.01 billion US dollars.

(5) 2010 Floods. Heavy monsoon rains occurred in Khyber Pakhtunkhwa, Punjab, Sindh and Balochistan Provinces in late July. One-fifth of the country was inundated, about 20 million people affected, and residents' properties, infrastructure and arable lands destroyed, and nearly 2,000 people died. The direct economic losses were about 10 billion US dollars.

(6) 2011 Floods. From August to September, the rainfall in the surrounding areas of Sindh, Balochistan and Punjab Provinces was far above the historical average, and a large area from Shahid Benazirabad to the coastal areas far from the left bank of the Indus River was inundated. About 2.75 million hectares of land were inundated in 23 districts of Sindh Province, 12 districts of Punjab Province and one district of Azad Jammu and Kashmir Province. As a result, 516 people died, about 1.6 million houses were damaged, and about 930,000 hectares of cultivated lands inundated. The direct economic losses were about 3.73 billion US dollars.

1.5 Cause analysis of 2022 floods

1.5.1 Rainfall analysis

The monsoon precipitation in Pakistan in 2022 had the following characteristics: (1) Abnormally more precipitation. The average rainfall in the period from July to September, July and August were 387.2 mm, 177.6 mm and 190.5 mm respectively, which are 175%, 181% and 239% more than those of the same period of the normal year, the highest since 1961 (Fig. 6). (2) Frequent heavy rainfall processes. From July to September, there were 10 heavy rainfall processes, some of which were connected, with overlapping areas and large amounts of rainfalls (Fig. 7). (3) Extremeness in nature. In July and August, there were 14 and 21 meteorological stations respectively that witnessed their highest ever-monthly rainfall. The rainfall at the Padidan Station in Sindh Province in August was as high as 1,228.5 mm, among which 355.0 mm was recorded on August 19, marking the record for the highest monthly and daily rainfall in history. (4) Abnormal location of rainy areas. Anomalously abundant rainfall is occurred in south Pakistan and covered a wide range. The rainfalls in July and August in Balochistan and Sindh Provinces were obviously more than those of the normal period, marking the highest in the same period of history since 1961. According to preliminary

CamScanner

analysis, the return period of the rainfalls in July and August 2022 in south to Pakistan is generally more than 50 years, and that for some stations exceeded 200 years (Fig. 5).

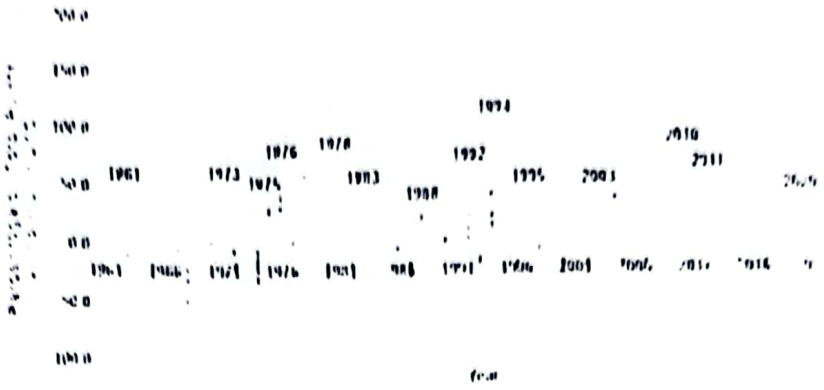
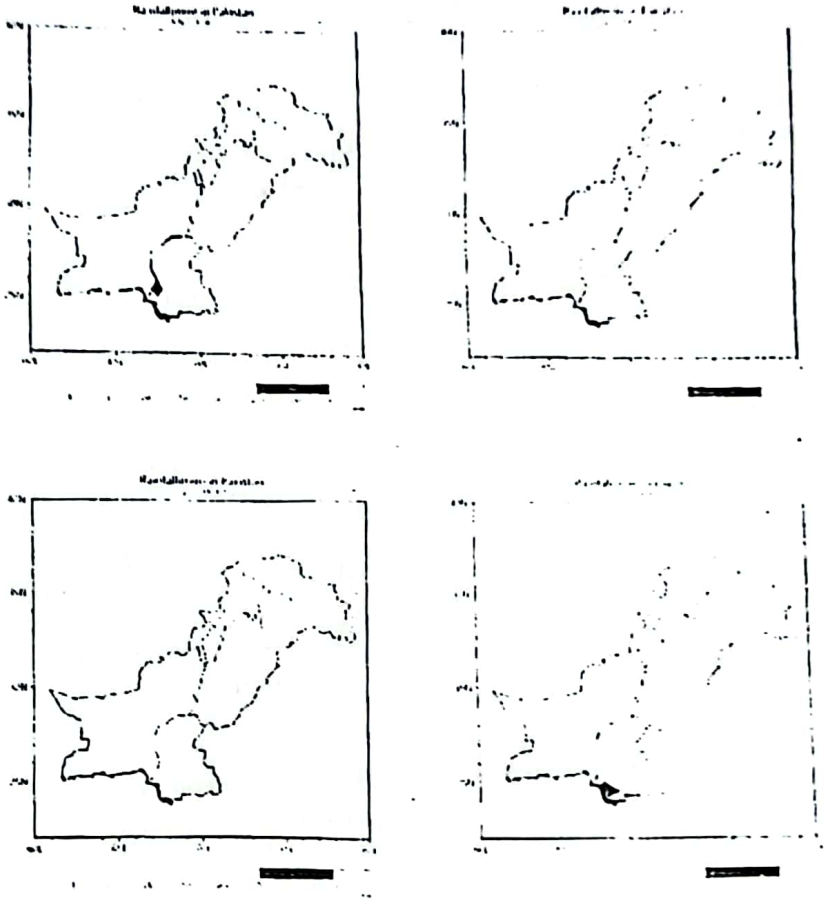


Fig. 6 Percentage of total rainfall anomaly in July-September in Pakistan from 1961 to 2022



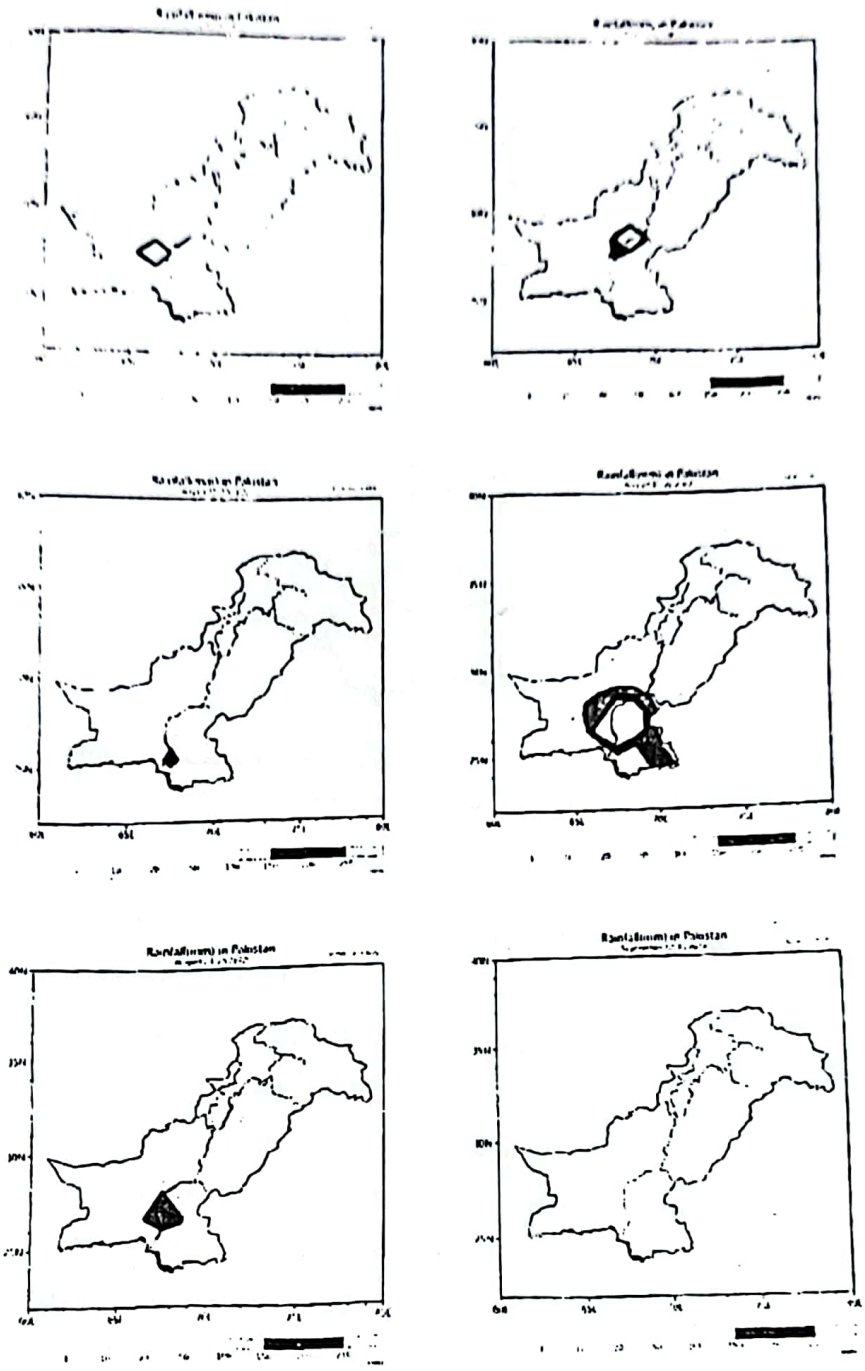


Fig. 7 Cumulative rainfall distribution of heavy rainfall processes in Pakistan from July to September in 2022

CamScanner

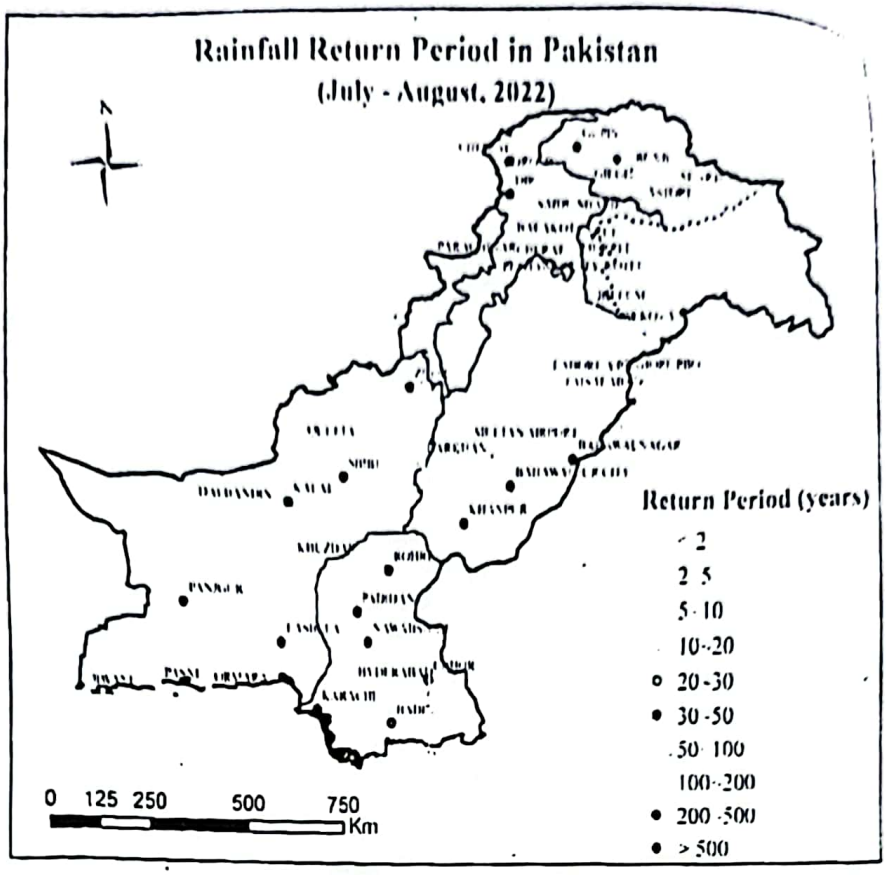


Fig. 8 Return period of rainfall in July and August 2022 in Pakistan

The cause analyses of rainfall variability are as follows: (1) Since 1950, most of the world has shown an increasing trend of extreme rainfalls, which is the climate background of extreme rainfalls in Pakistan this year. (2) This year's summer monsoon was unusually strong in the northern Arabian Sea and lasted for a long time. The summer monsoon carried a large amount of warm and humid air currents from the tropical Indian Ocean northward to Pakistan, northern India and other places, which repeatedly converged with the air currents from the northern continent over this area, resulting in many heavy rainfall processes. (3) The extreme rainfall anomaly in Pakistan was also the result of the synergy of the South Asian summer monsoon circulation and the East Asian summer monsoon circulation. This summer, the western Pacific subtropical high was unusually strong and westward, causing water vapor in the eastern Bay of Bengal to change its traditional eastward path and turn to northern India and Pakistan. Affected by this, the water vapor in southern Pakistan increased abnormally compared with the same period of previous years, and the low-altitude water vapor

convergence was extremely strong, w[illegible]

long period.

1.5.2 Flood analysis

The peak discharge in 2022, return period and historical extreme values at the main control stations on the mainstream and major tributaries of the Indus River are shown in Fig. 9, which reflects that the return period of flood in the mainstream and tributaries of the Indus River in 2022 is mostly less than 5 years, making it a common flood in general.

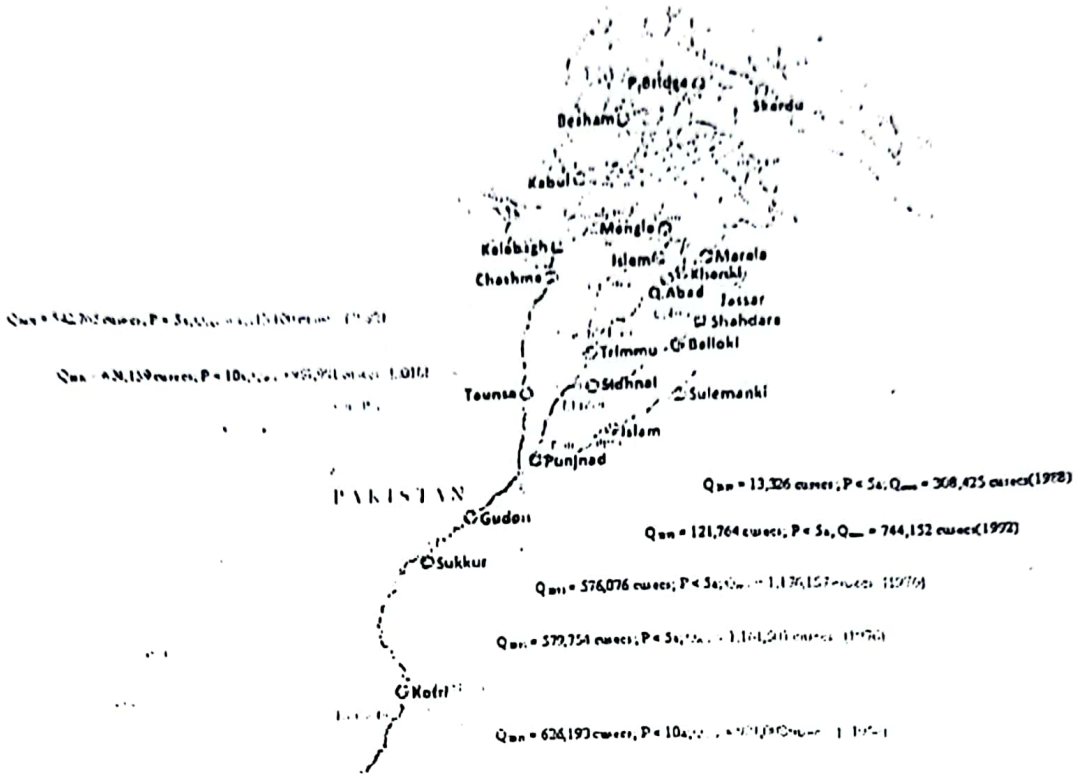


Fig. 9 Diagram of 2022 peak discharges at main control stations along the Indus River

The rainfall processes from July 4 to July 9, from July 11 to July 18 and from July 22 to July 31 led to flash floods in Balochistan Province, raised the water level of rivers in plain areas such as Punjab Province, increased soil moisture content, and weakened the subsequent flood regulation and storage capacity of local rivers and lakes. The rainfall in August and September led to repeated disasters in Balochistan Province, and flash floods broke out in many places in Balochistan Province and western Sindh Province, destroying flood protection dikes and significantly increasing the difficulty of drainage in nearby plain areas. Although

CamScanner

the generally frequent floods in the lower reaches of the Indus River did not cause dy, breaches along the mainstream, the high water level of the mainstream was not conducive n, drainage for the nearby plain areas, especially for arid and semi-arid areas, which suffered the most extremely heavy rainfalls in the same period since 1961 from July to September, resulting in severe waterlogging rarely seen in history. This was the main cause of the disaster.

The discharge of the mainstream Indus River at the Taunsa Station was between 100,000 and 100,000 cusecs before late August, 2022 after which there was an obvious rising process of water level, and the peak discharge on August 31, 2022 was 624,159 cusecs (Fig. 10). The high water level of the mainstream led to the poor drainage and waterlogging in plain area, which aggravated the disaster losses to a certain extent.

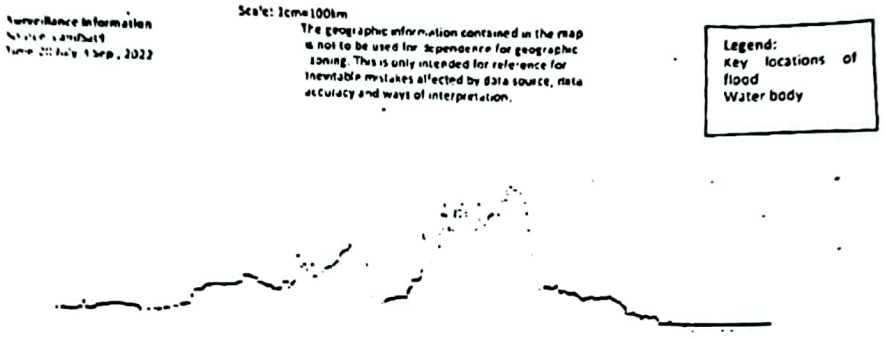


Fig. 10 Flood Process at Taunsa Station, mainstream Indus River (Source: the PMD)

To sum up, the catastrophic flood disasters in 2022 were mainly caused by normal riverine floods in the mainstream Indus River superimposed on the extremely heavy rainfall in the western mountainous and plain areas downstream. Against the background of global climate change, extreme weather and climate events occur more frequently and with greater severity, hence the scientific attribution of this extreme rainfall event needs to be further revealed.

1.6 Disaster response and rescue

As of October 21, this year's floods had affected 33.046 million people in 85 prefectural districts, killed 1,731 people, injured 12,867 people, partially damaged 1.393 million houses

and completely destroyed 891,000 houses, killed 1.164 million livestock, damaged 13,115km roads of and 439 bridges.

Disaster response and rescue were mainly organized and coordinated by the national, provincial and prefectural disaster management authorities. With the rapid development of the disaster situation, the Government of Pakistan declared a state of emergency on August 25, 2022 and requested assistance from the international community. On August 29, 2022, the Joint Party Conference of Pakistan decided to set up the NFRCC, directly under the responsibility of the Prime Minister of Pakistan. Its members included the relevant departments of the federal and provincial governments and the armed forces of Pakistan. Specific executives were appointed by the federal government, and specific coordination fell under the responsibility of the NDMA. Pakistan's army, navy and air force sent teams to assist in search, rescue, evacuation, resettlement of flood-affected people, and transportation and distribution of disaster relief materials.

Relevant countries and the international community actively supported Pakistan's rescue and relief works. China was one of the first countries providing disaster relief assistance to Pakistan. President Xi Jinping and Premier Li Keqiang extended condolences to Pakistani President and Prime Minister respectively, and the Chinese government responded immediately and provided large amounts of emergency relief materials and financial assistance to Pakistan to support flood control and disaster relief and post-disaster reconstruction work. The total amount of flood relief assistance provided by China to Pakistan has exceeded 644 million RMB yuan, the most among all countries. The United States Government announced that it would provide 56 million US dollars for flood control and disaster relief and humanitarian assistance. The United Arab Emirates sent 22 flights delivering relief supplies worth 50 million US dollars.

The United Nations agencies and international organizations responded positively. UN Secretary-General Guterres visited Pakistan's disaster-stricken areas from September 9 to 11, 2022 and agreed to launch the 2022 Pakistan Flood Response Plan. The newly revised response plan called for a fund raising of 816 million US dollars for 9.5 million victims. The United Nations General Assembly adopted a resolution on October 7, 2022 urging the

CamScanner

international community to provide full support and assistance to the Government of Pakistan in its efforts to mitigate flood disaster impacts and meet medium- and long-term recovery and reconstruction needs. The World Bank provided 350 million US dollars in flood control and disaster relief assistance. The World Food Programme provided 110 million US dollars for disaster rescue and relief operations.

2 Aspects for Further Improvement

The federal and local governments of Pakistan have attached great importance to flood control and DRR. Yet at present, the Pakistani flood control and DRR system is not sound enough, with limited defense capability that makes the impacts of major floods on economic and social development obvious. The major existing aspects for further improvement mainly include the following 7 aspects:

2.1 The accuracy of flood monitoring, forecasting and early warning system needs to be improved

Pakistan has established a relatively complete rainstorm flood monitoring, forecasting and early warning system, yet there are still deficiencies in terms of accuracy, leading time of forecasting, and early warning means. (1) The network of meteorological and hydrological monitoring stations is sparse and does not reach the minimum density standard of precipitation stations, hydrological stations and evaporation stations proposed by the World Meteorological Organization. The application of satellite and radar technology needs to be improved, and monitoring of glacial snowmelt floods and GLOFs needs to be strengthened urgently. (2) There is a lack of a unified national database to support real-time information sharing. (3) The accuracy of extreme weather and climate event forecasting and seasonal forecasting needs to be continuously improved. (4) The accuracy of underlying surface characteristics of small watersheds and their basic attribute data, and the distributed hydrological model and hydrodynamic model need to be improved.

2.2 The systematization of flood control plannings and the coordination of flood control standards in the Indus River Basin should be enhanced

Pakistan has prepared four rounds of national flood control plannings. The first two rounds focused on the construction of flood protection dikes, riverbank revetments, groins and other structural measures in cities and river reaches with weak flood control capacity and with key infrastructure located. In the third round, the focus shifted to non-structural measures, including institutional reform, flood early warning system construction, flood risk mapping, etc. The fourth round is more comprehensive, including almost all aspects of structural and

CamScanner

non-structural measures. In general, however, the projects proposed in the above-mentioned plannings are numerous and relatively scattered. It is not scientifically arranged to establish a flood control engineering system with the consideration on providing flood outlets from the overall perspective of the entire river basin. Although the objectives of reducing flood peaks and inundation extents, reducing vulnerability and mitigating flood impacts are proposed, they are mostly qualitative goals, rather than putting forward the quantitative objectives of basin planning. Flood control standards for the river basin and regions are not coordinated, and design standards for structures are inconsistent, which makes it difficult to guide the planning and design of engineering systems including reservoirs, dikes, drainage systems and other structures. Similar problems also exist to varying degrees in the plannings of relevant federal agencies and provincial departments.

2.3 There is no pivotal flood control reservoirs in the upper reaches of the Indus River, and the flood control regulation of the river basin needs to be strengthened urgently

Most of the existing reservoirs in the upper reaches of the Indus River have not reserved flood control storage capacity, serving mainly for power generation and irrigation, making them difficult to effectively play the role of flood regulation in case of major floods. Even if they played a certain role in flood storage in some years, it was mostly a temporary response due to the lack of flood control regulation schemes to interact the upstream and downstream as a whole. It is an urgent task to build a batch of flood control reservoirs in the upper reaches of the Indus River Basin, to strengthen the means of flood control in the basin, retain the upstream floods and reduce the flood peaks according to the downstream flood control needs. In addition, it is necessary to further strengthen the joint flood control operation of reservoirs, barrages, dikes and flood detention areas according to the combination characteristics of typical flood superposition, so as to give full play to the overall benefits of the flood control engineering systems in the basin.

2.4 The flood prevention and flood regulation schemes of the Indus River Basin need to be prepared urgently

The Indus River almost traverses the entire territory of Pakistan, and flood control and DRR

CamScanner

involve many departments of the federal government, and provinces and special districts along the river. In the case of emergency such as major floods, the multiple authorities may find it very difficult to coordinate temporarily, and hard to achieve unified goals and mutually recognized principles, often resulting in a scattered input of resources, attentions and efforts for flood control and less outcomes. It is urgently needed to formulate authoritative and binding flood prevention schemes and flood control regulation schemes for the Indus River Basin, to encourage a systematic and holistic thinking, and to formulate prevention countermeasures and plans in advance for different types of floods that may occur based on the existing flood control engineering systems and natural geographical conditions. This will provide a reliable basis for relevant departments and local authorities to implement commanding decisions on flood control operations, rescue and disaster relief. In this way, the joint efforts of united flood fighting and efficient emergency response shall take shape.

2.5 The drainage systems for areas downstream of the upper reaches of the Indus River have deficiencies with low drainage capacity

Most areas downstream of the upper reaches of the Indus River are traditional arid and semi-arid areas. With the climate change, however, many rainfall processes with high intensity in a few years were occurred, and the abnormal heavy rainfalls in the region overwhelm the existing drainage capacity. The problems of imperfect or even missing drainage systems and generally low drainage capacity are becoming increasingly prominent. At the same time, the plannings of drainage systems and road networks are not coordinated, highlighted by the problems of serious flood blocking around across river structures such as bridges, large-scale reclamation, narrowing of cross sections of flow passages in river courses, fragmentation of land patches and phenomenon of waterlogging backflow in local areas. There is also a phenomenon that some irrigation and drainage canals are blocked during heavy rainfalls, resulting in waterlogging that cannot be drained in time. It is necessary and urgent to improve the drainage systems and enhance the drainage capacity in the areas downstream of the upper reaches of the Indus River.

2.6 There is no effective means and emergency plans to deal with rainstorm floods exceeding design standards

CamScanner

According to the *National Flood Control Plan IV*, when the mainstream of the Indus River is flooded and the water level of the river exceeds the design level of the mainstream dike, a spillway may be opened to divert water into the southern desert area. But this is only a preliminary idea, and a specific planning design scheme needs to be put forward on the basis of sufficient assessment. In addition, there is no effective solution to the drainage problem of heavy rainfalls in farmlands and towns exceeding the existing drainage capacity. There is no specific implementation plan for the planned drainage capacity improvement projects. The whole Indus River Basin, as well as the key areas and key flood control projects in the basin, have the problem of how to deal with flood risks caused by rainstorm floods exceeding design standards to varying degrees. It is necessary to plan and construct temporary flood diversion and discharge facilities and shelters in advance, and to formulate emergency plans such as evacuation.

2.7 The problems of sediment deposition and river regime stability are becoming increasingly prominent

The annual sediment discharge of the Indus River is more than 200 million tons, and the main sediment yield area is located in the upper reaches. The particle size of suspended sediment gradually decreases towards the lower reaches. The upstream reservoirs of the Indus River, especially the Tarbela and Mangla Reservoirs, have intercepted most of the incoming sediment, significantly reducing their effective storage capacity. Most of the existing sluices and barrages also have sediment deposition problems, which have imposed adverse effects on their safe operation and normal benefits of the projects. The siltation in the lower reaches of the Indus River is becoming more and more prominent, resulting in the aggradation of the riverbed, poor flood discharge capacity and frequent migration of the main river channel, which further aggravate the losses of flood disasters. From the perspective of sustainable development of the whole basin, it is an urgent task to carry out overall planning and systematic management of the river basin by comprehensively considering the issues of reservoirs, river sediment control and river regime evolution.

CamScanner

3 Experiences of Flood Control and DRR in China

China is one of the countries with the most serious flood disasters in the world. Thanks to unremitting efforts over a long period of time, more than 320,000 km of dikes above Grade V and more than 98,000 reservoirs have been built, and flood control and DRR engineering systems consisting of dikes, reservoirs and flood storage and detention areas have been established in the mainstreams of major rivers. The main river reaches have gained the capacity to prevent the largest floods that have actually occurred since 1949. The core of China's flood control and DRR strategy is to regard a river basin as an interrelated and interactive complex system, and to pursue the sustainable development of the whole river basin, maximizing long-term interests and overall benefits. The objectives, standards, overall layout and project priorities of flood control and DRR in the river basin are clarified in stages, and incorporated into the strategic planning and five-year plan of relevant industry departments from the central government to local governments, which are implemented step by step according to their priorities. Such objectives, standards, overall layout and project priorities are constantly summarized, reflected and improved. Main experiences are categorized into the following aspects:

(1) Upholding the leading of planning and realizing the coordination of all aspects and standards. At the national level, China formulates long-term strategic plannings with the philosophy of "implementing the blueprint thoroughly", formulating consecutive five-year plannings for national economic and social development. Long-term plannings are made for major national projects, the distribution of productive forces and important proportions of the national economy, and goals and directions set for the long-term development of the national economy. Under the guidance of territorial development planning, China implements multi-planning integration under a master plan, and formulates development plannings in different industries to guide development, such as lake protection planning, urban construction planning, flood control planning and navigation planning. In terms of flood control, a river basin flood control planning is formulated by taking into account water regime, flood control objectives, flood control standards, engineering layout, structural measures, non-structural measures and implementation plans. Under the river basin flood control

CamScanner

planning, there are special plannings and regional plannings, and the lower-level plannings should be subordinate to the upper-level ones.

(2) Highlighting key objectives in stages and implementing them step by step according to their priorities. The concept and measures of water governance should be adapted to the level of economic development. China built dikes, reservoirs and flood detention areas mainly preventing riverine floods from 1949 to 1977 (the first stage), and focused on solving regional flood and waterlogging problems caused by rapid economic development and the space shrinking of rivers and lakes from 1978 to 1997 (the second stage), and made efforts to build urban flood control protection circles with a focus on river dike reinforcement and riverplain management in view of the flood control needs put forward by rapid urban development from 1998 to 2012 (the third stage). Since 2012 (the fourth stage), China has adhered to a green development concept, implemented systematic management by taking a river basin as a unit, optimized the pattern of territorial development, and designed cities according to flow regimes. The *National Planning for Prevention and Control of Flash Floods* has been implemented step by step, and a flash flood disaster prevention system suitable for China's national conditions creatively established, which has significantly reduced casualties. The priority of flood control project construction has been clarified, and the construction proceeded step by step. For example, in order to solve the problem of flood control in the Yangtze River Basin, China has determined the construction priorities of various flood control projects based on comprehensive comparison of their effectiveness. At the same time, the flood control standard systems in a river basin should be coordinated, and the corresponding flood control standard be set according to the importance of protected objects. There are high or low standards for the flood control of urban and rural areas, mainstreams and tributaries, which may not necessarily be the same. Thus, in case of major floods, the pressure of flood control on the mainstream will not be increased. During emergency, some key places shall be protected with full-on efforts and some may be given up.

(3) Emphasizing flood Prevention First, paying attention to various flood preparedness measures, and taking the initiative to prevent and avoid disasters. Responsibility is assigned to specific officials, and the responsible persons for flood control and drought relief

CamScanner

of governments at all levels as well as the responsible persons for major rivers and important projects are publicized to facilitate social supervision. Potential disaster risks are investigated and rectified, damaged flood control projects repaired, and measures implemented to ensure safety against floods. According to economic, social and engineering changes, the master plan for flood control and drought relief and special plans for flash flood, reservoir flood control and emergency activities in dangerous dike situations (including the response on floods exceeding design standards) are updated and improved annually. Governments at all levels and their flood control and drought relief headquarters hold annual flood control and drought relief meetings to fully deploy the annual key tasks. China carries out disaster prevention and mitigation training and drills, strengthens the capacity building of the professional emergency response teams, and supplements emergency rescue and disaster relief materials. Public education outreach on disaster prevention and mitigation has covered enterprises, rural areas, communities, schools and families, so as to improve public awareness of disaster prevention and avoidance, and increase people's ability to perform self-rescue and mutual rescue. China has established a six-level (village-township-county-city-province-ministry) disaster reporting system and a national natural disaster management system, and set up a disaster reporting force of more than 1 million grassroots informants with regular training.

(4) Coordinating and cooperating during disasters, and effectively synergizing departments, central and local governments. The State Flood Control and Drought Relief Headquarters of China, composed of 25 national departments, is a permanent deliberative and coordinating body, with the leadership of the State Council as the general commander, responsible for overall coordination, command and dispatch of flood control and drought relief throughout the country. The Headquarters organizes joint consultations, coordinates emergency response, and unifies command and dispatch. The Ministry of Emergency Management (MEM) assume the standing office of the flood control and drought relief headquarters, responsible for organizing and coordinating actions, confirming rescue teams and materials, and organizing disaster relief and assistance. Meteorological departments carry out real-time forecasting and timely issuance of rainstorm and severe convective weather warnings. Water resource departments are responsible for flood monitoring, forecasting and

CamScanner

early warning, using flood control projects to regulate and control floods, and reinforcing the operation management and safety inspection of rivers and flood control structures. Natural resources departments organize monitoring and early warning of potential geological hazards. Departments of housing, urban and rural construction, transportation and energy organize flood control and drought relief actions in their respective industries in accordance with their respective responsibilities. At critical moments, the state dispatches taskforces and expert groups to key areas to assist in flood control, flood fighting, rescue and disaster relief.

(5) Carrying out joint flood control operation with engineering systems by relying on flood forecasting, decision-making assistance and other information systems. Based on the basic principle of "interception in upper stream, storage at middle stream and discharge for lower stream", precise and unified flood regulation is implemented basin-wide, taking into account the multiple needs of mainstream and tributaries, upstream and downstream, left and right banks, flood control, drainage, power generation, water supply, navigation, irrigation and ecology. China has accomplished a set of advanced information systems including meteorology and hydrology forecasting and early warning systems, as well as decision-making assistance and command systems, which provide precise support for flood control with engineering systems. For example, 111 important water projects of reservoirs, flood storage and detention areas, pumping stations, culverts and sluices have been included for joint operation in the Yangtze River Basin (with a catchment area of more than 1.8 million km^2). The number of stations for real-time hydrological and precipitation information in the basin is now more than 30,000. Combined with the quantitative precipitation forecast and short-, medium- and long-term hydrological forecast in the Yangtze River Basin, a flood regulation decision-making scheme is formed through real-time deduction with the help of the Yangtze River flood control forecast and regulation system.

(6) Coordinating professional forces as well as local people to enhance inspections, defense and emergency protection of projects. China attaches great importance to improving emergency response force systems and comprehensively promoting the emergency response capacity building of professional teams and grassroots communities. The national comprehensive fire rescue force (China Fire and Rescue) is the main force and national team

CamScanner

of emergency rescue, while the Chinese People's Liberation Army and the People's Armed Police act as flood fighting and rescue commandos. Professional teams such as engineering construction teams are also important cooperative forces for flood control and rescue, assisted by non-governmental forces. If riverine flood level is below a warning level, engineering management organizations under the jurisdiction of water resources departments are mainly responsible for the inspection of dikes. If riverine flood level exceeds a warning level, local government takes over the inspection and emergency protection of dikes. Emergency rescue forces and equipment shall be preset in advance in dangerous sections of projects and weak dike sections, so as to minimize the risk of disasters. If riverine flood exceeds a certain level, governments will strengthen social mobilization, declare an emergency flood season when necessary, and mobilize all forces to participate in flood fighting and disaster relief.

(7) Allocating graded responsibility for post-disaster recovery and reconstruction, and perform reviewing, assessing and countermeasures improving to major natural disasters in time. People affected by disasters shall be properly resettled, with their access to food, clothing, clean water, safe shelters, education, health and epidemic prevention measures ensured. It is guaranteed that the most vulnerable affected populations shall be properly supported. If the losses caused by natural disasters reach the national response level, relevant actions shall be taken in accordance with the national emergency plan for natural disaster relief, of which the working procedures and contents are standardized. The recovery and reconstruction of houses and infrastructure damaged by disasters shall be organized and carried out by local governments, of which the houses shall be mainly built by affected households themselves. The people's governments at county level shall be responsible for organization and implementation of house recovery and reconstruction. The reconstruction planning and housing design shall be determined according to disaster situation and local conditions. Site selection shall be scientifically managed, and disaster resistance and fortification capabilities improved to ensure the safety of reconstructed houses. The state will formulate special plannings for the recovery and reconstruction of major natural disasters and provide various support in relevant fields. After each major flood disaster, assessment and review will be organized by the central and local government to identify the causes of the

CamScanner

4 Comments and Recommendations

In line with global climate change and economic and social development, the frequency and disaster risks of extreme rainstorm floods might be on the rise. Based on field investigations in Dadu City and Mirpur Khas City of Sindh Province and discussions with relevant departments and experts, taking into account the limited information and data collected and comprehensive consideration of Pakistan's national conditions, flow regime and management mode, the Chinese Expert Group puts forward the following comments and staged recommendations for reference after conscientious analysis and study.

4.1 Focuses in the near future

At present, many areas in southern Pakistan are still inundated. Many affected people remain homeless or are living in emergency shelters, with local transportation and communications not yet fully restored and large areas of crops destroyed, causing food shortage risk. Meanwhile, waterlogged areas are prone to become breeding grounds for infectious diseases, and thus the risk of secondary disasters increases, and the tasks of disaster relief and post-disaster reconstruction are extremely arduous. In the near future, Pakistani authorities need to focus on strengthening the works in the following areas:

(1) Relieving disaster-affected people. It is recommended that Pakistan should conduct a thorough and meticulous investigation of the number of people affected by the disaster as well as their basic living conditions, scientifically and rationally select centralized and decentralized resettlement sites, continue to raise, transport and distribute urgently needed food, drinking water, clothing, blankets, tents and other materials to the suffering people in a timely manner, and actively create conditions to ensure that those affected have food, clean water, clothing, medication and safe shelters.

(2) Accelerating waterlogging drainage. It is necessary to organize personnel and extra equipment to increase the capacity of farmland drainage, to dredge drainage channels as soon as possible, and to create basic conditions for the restoration and reconstruction of livelihood and living order in disaster-stricken areas. Agricultural machinery and facilities should be holistically dispatched, and DRR, loss reduction, emergent seeding and emergent harvesting

CamScanner

should be carried out as soon as possible.

(3) Strengthening epidemic prevention, disinfection and medical treatment in disaster-stricken areas. It is recommended that Pakistan should improve emergency monitoring of drinking water for prevention and control of infectious diseases after the disaster, and seek to eliminate viruses in waterlogging areas and resettlement areas for the transferred masses, so as to prevent the spread of the epidemic. It is also recommended that Pakistan should quickly dispatch medical teams to the disaster-stricken areas, carrying medical equipment and medicines for medical services to meet the basic medical needs of the people.

(4) Organizing post-disaster review and improvement. Governments at all levels and relevant departments and stakeholders should comprehensively review the occurrence and response process of the catastrophic flood disaster in 2022, analysis on shortcomings, sum up experiences and lessons, and put forward improvement measures and countermeasures. Then it is recommended that Pakistan should strengthen the application of the review results to provide decision-making reference for further improvement of flood fighting and disaster mitigation.

(5) Scientifically formulating post-disaster recovery and reconstruction plans. On the basis of review and introspection, it is recommended that Pakistan should develop a scientific and rational post-disaster reconstruction plan for infrastructure, civil buildings, construction standards and structure types according to the results of flood risk mapping, coordinating different industries and regions in view of the present conditions and future development. Federal and local governments at all levels should strengthen coordination and promote post-disaster recovery and reconstruction work in an orderly manner.

(6) Reconstructing damaged residential houses as soon as possible. Planning and construction should be carried out with government guidance combined with residents' wishes, combining centralized resettlement with decentralized resettlement and nearby resettlement with emigration resettlement, with the purpose of ensuring long-term livelihoods. Residential sites should be selected to avoid the areas with high flood risk or prone to flash

CamScanner

floods, geological disasters or riverine floods of small and medium-sized rivers. Residential areas within river courses or flood passage areas should be moved out as far as possible, taking advantage of the opportunity of post-disaster reconstruction to return space to the river.

(7) Accelerating the repair of infrastructure damaged by floods. It is recommended that Pakistan should speed up the maintenance and reconstruction of meteorological and hydrological monitoring instruments and facilities, quickly restore monitoring capacity, and provide guarantees for the normal operation of flood prediction and forecasting services in disaster-stricken areas. It is recommended that Pakistan should speed up the restoration of infrastructures such as transportation, electricity, communications and water conservancy, especially the lifeline projects for disaster prevention and relief. When repairing or rebuilding, areas vulnerable to flooding and impact should be avoided, and the flood control and waterlogging prevention capacity of backbone lifeline projects be properly improved, and emergency measures and emergency plans for rapid recovery in case of rainstorms and floods exceeding design standards be formulated.

4.2 Focuses in the medium-term future

The rapid development of economy and society has brought about higher safety requirements for flood control and waterlogging elimination. In order to gradually improve the capability of flood control and DRR system in Pakistan and fundamentally avoid the obvious adverse effects of frequent rainstorm floods on economic and social development, it is recommended that the following works should be strengthened in the medium-term future in accordance with the principle of small investment with quick benefit returns:

4.2.1 Accelerating the integration of flood control plannings within the Indus River Basin

It is recommended that Pakistan should quickly make full use of and integrate the existing flood control plannings, water conservancy plannings and irrigation area improvement planning formulated by the federal government and its relevant departments, and relevant provinces to form a holistic and systematic flood control planning for the Indus River Basin. The flood control planning of the Indus River Basin should strengthen the concept of

CamScanner

basin-scale systematic management, clarify the flood control standards of key areas and key protected objects, coordinate the mainstream and tributaries, upstream and downstream, left and right banks, and scientifically design the flood control layout. The idea of a flood control and DRR engineering system characterized as "interception in upper reach, diversion at middle reach, discharge for lower reach and detention in low-lying areas" is preliminarily proposed as follows.

(1) Constructing upstream reservoirs for storage. In combination with the flood control objectives of the basin, it is recommended to formulate an upstream reservoir cluster construction plan and specific construction schemes, speed up the feasibility study and approval of the existing reservoir construction scheme (Fig. 11), start the construction of pivotal flood control reservoirs as soon as possible, and explicitly stipulate the flood control operation mode of a single reservoir and reservoir clusters.

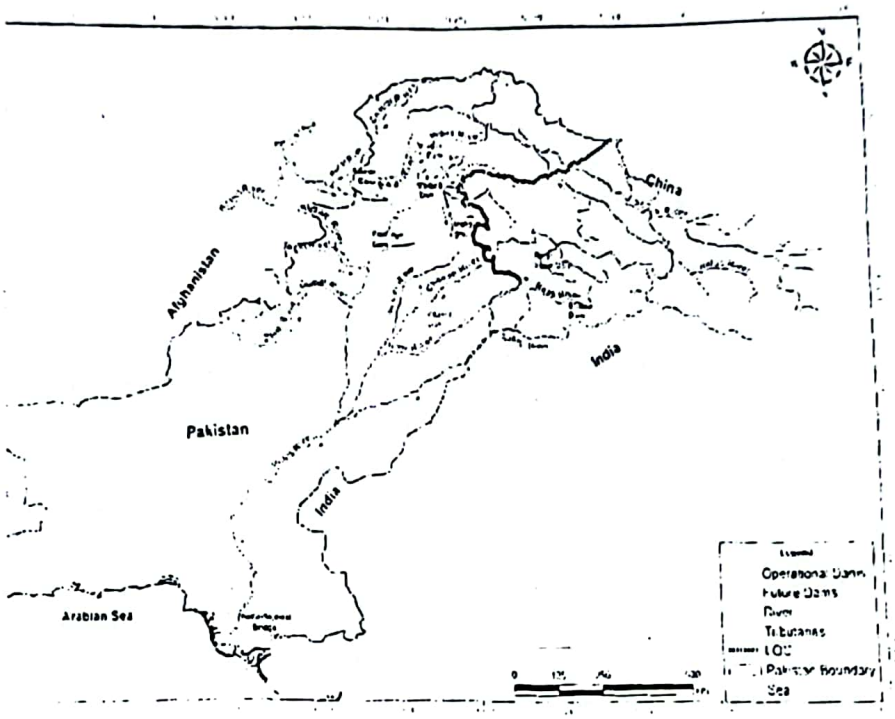


Fig. 11 Layout of planned and constructed reservoirs

(2) Restoring the flood discharge capacity of the river channel. The lower Indus River is a migrating plain river with its course varying in width by several kilometers. Some barrages

and large-scale bridges have intruded on the river course to varying degrees, and local river cross-sections are obviously narrowed, disabling effective and quick discharge of floods, and may form a backwater rise of the upstream river section, resulting in the overflow and breaches of dikes and bringing about great potential hazards to flood control. In combination with the flood control planning of the river basin, it is recommended that Pakistan should pay close attention to the regulation and removal of obstacles in the river course of the lower Indus River, and restore the normal flood discharge capacity of the river reaches seriously occupied by barrages and bridges. Meander cutoff or river channel strengthening project involves complex issues such as upstream and downstream relations, river regime stability, and land and water resources utilization on both sides of the river, which need to be treated with caution. Any planned meander cutoff scheme (Fig. 12) must be fully evaluated before implementation.

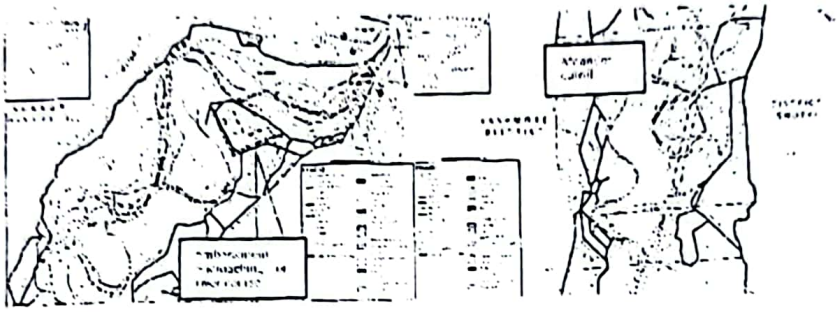


Fig. 12 Schematic Diagram of Recovery of Flood Discharge Capacity and meander cutoff of Typical River Section

(3) Constructing flood diversion projects. There are two preliminary ideas for flood diversion projects, which do not qualify as sound recommendations due to the lack of either a topographic contour map or a groundwater depth distribution map. The first is the flood diversion works (brown line) of the Rainee Irrigation Canal on the left bank upstream of the Guddu Barrage, proposed in the existing planning to divert the excess flood to the eastern desert (Fig. 13), but the scale of this project is relatively large, and there may be adverse environmental impacts and sediment deposition problems, which need scientific evaluation. The second is to build a flood diversion channel to connect the western dike (green line) to be used to intercept flash floods from the right bank upstream of the Guddu Barrage (① red line)

CamScanner

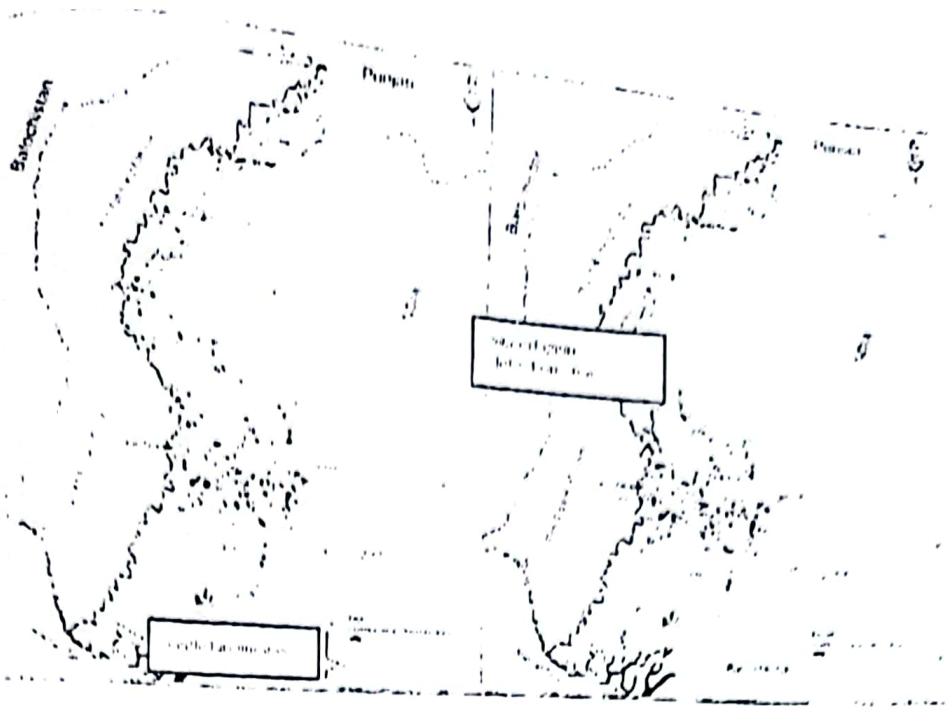


Fig. 14 Spatial distribution of waterlogging in plain area of southeast Sindh Province

4.2.2 Determining the priority order of project list and promoting orderly project construction

The distribution, types, functions and construction standards of flood control and drainage projects should be systematically organized in line with the economic development layout of the Federation and relevant provinces and in accordance with the flood control planning of the Indus River Basin. In the medium-term, projects with small investments and quick benefit returns may be arranged, and important key projects in the river basin or regions should be evaluated.

(1) Implementing projects with small investments and quick benefit returns. Priority should be given to the construction of flood control reservoirs in the upper reaches of the Indus River, especially multi-purpose reservoirs with both social and economic benefits. It is necessary to formulate a more systematic layout planning for irrigation and drainage canals, in which priority should be given to the restoration of ancient river channels and the improvement of drainage capacity of low-lying areas. The across river structures that affect river flood discharge should be upgraded in terms of flood discharge capacity, local bottle-neck sections should be rectified, the dikes of key river sections should be heightened and reinforced, the deficiencies of flood control in the river basin should be defused, the ratio

CamScanner

of projects satisfying flood control standard of the river basin should be increased, and the defense capacity of key river reaches should be improved.

(2) Conducting feasibility studies of key projects with special importance. It is recommended to conduct the feasibility studies for the construction of pivotal flood control reservoirs in the upper reaches of the Indus River and its major tributaries, the sediment discharge facilities for new reservoirs, the maintenance of effective storage capacity of existing reservoirs, the construction of dikes in the lower reaches of the Indus River and western Sindh Province, the restoration of flood discharge capacity in the lower reaches of the Indus River, the improvement of the LBOD drainage capacity in Sindh Province, and the flood diversion project for the prevention of flood exceeding design standard in the mainstream of the Indus River. The viable projects by feasibility studies should be incorporate into the national and provincial strategic planning. They should be implemented step by step in accordance with their priority orders.

4.2.3 Establishing a complete national flood forecasting and early warning system

It is recommended to make full use of modern theories and technical methods to gradually improve the fineness of flood monitoring, forecasting and early warning systems, and build a well-rounded national flood forecasting and early warning system.

(1) It is recommended to prepare the scheme of a flood monitoring, forecasting and early warning system for the Indus River Basin by making full use of modern meteorological, hydrological and hydrodynamic theories and methods and based on big data technology.

(2) It is recommended to complement the construction and upgrading of meteorological and hydrological monitoring stations, to expand and deepen the application of satellite and precipitation radar technology, to realize real-time and accurate sharing of all kinds of forecasting and monitoring information, and to build a national high-resolution comprehensive database containing all elements of space-air-ground hydrometeorology and hydraulic project data.

(3) It is recommended to develop the rainstorm flood forecasting and early warning model according to hydrological zoning, and improve the established flood forecasting and early

CamScanner

warning systems, to extend the forecast lead-time, and improve the forecasting accuracy and early warning capacity.

(4) It is recommended to improve rainstorm flood early warning mechanisms and release flood forecasts and early warning information in time, to realize reliable interaction between flood control authorities and disaster relief authorities.

4.2.4 Strengthening the unified flood control regulation of the Indus River Basin

Flood control and DRR in the Indus River Basin concerns the national economic and social development of Pakistan. The relationship between the mainstream and tributaries, upstream and downstream, and left and right banks is so complex that a slight change in one part may affect the situation as a whole. It is necessary to gradually implement the unified management of flood control regulation throughout the whole basin.

(1) It is recommended to formulate an authoritative and binding flood prevention plan for the Indus River Basin by the federal government. In accordance with the principle of "ensuring safety against floods within a design standard and mitigating the disasters of floods exceeding design standard", the flood control efforts in the river basin should be deployed and arranged as a whole. The plan will serve as an important basis for implementing flood control decision-making and disaster relief by flood control headquarters at all levels.

(2) It is recommended to formulate an authoritative and binding flood control regulation scheme for the Indus River Basin by the federal government. According to the determined flood control standard and the design flood in the Indus River Basin Flood Prevention Scheme, considering current flood control capacity of existing flood control system, reasonable arrangements shall be made for different types and magnitudes of floods. Flood regulation mode, commanding authority, structural defense and emergency response, evacuation and aftercare of the people in dangerous areas, the responsibilities and obligations for flood control and flood fighting shall be clarified.

CamScanner

4.2.5 Accelerating the construction of drainage facilities and flood shelters in cities, towns and key flood-prone areas

It is necessary to systematically analyze the characteristics of the major flood and waterlogging disaster losses and the trend of extremely heavy rainfalls in the past two decades, and determine the key cities, towns and flood-prone areas for flood control and drainage in the whole country. Then, it is necessary to formulate drainage and flood shelter schemes by following the principle of "specific solution for specific city, and specific solution for specific point" and in accordance with the flood control planning of the river basin, as well as pay attention to the coordination among them. For areas downstream of the upper reaches of the Indus River, safety platforms should be built near densely populated residential areas as temporary flood shelters in case of extreme rainstorm floods. Building materials may come from river dredging or desilting, high earthfill areas near irrigation channels and drainage channels, or the abandoned soil from the excavation of newly established drainage detention areas. In addition, in the post-disaster reconstruction of governmental management facilities, public service facilities and schools, flood-resistant buildings with more than two floors should be built as disaster shelters or front-line command posts for disaster prevention and relief.

4.2.6 Strengthening national emergency response capacity

It is an important non-structural measure to strengthen national emergency response capacity to effectively reduce casualties and rapidly carry out rescue and disaster relief, given the current situation that the capacity of flood control and DRR engineering systems is slow to develop.

(1) It is recommended to formulate a national emergency response capacity building planning, establish and improve an interdepartmental professional rescue team and grass-roots non-governmental team system, build a national emergency rescue force promotion and evaluation system, enhance the professional level of rescue forces in the industry, and strengthen resource sharing, information sharing and joint training of various rescue forces.

(2) It is recommended to establish a team system of six-level disaster informants from the

CamScanner

federation to villages, and improve the ability of disaster informants in disaster information collection, transmission, collation and analysis through regular training to ensure timely and accurate reporting of disaster information level by level after a disaster.

(3) It is recommended to establish reserve quota standards for emergency materials and equipment for emergency flood fighting, disaster relief and assistance, and gradually build up these reserves. The training, exercises and popular science education of disaster prevention and risk avoidance should be organized and carried out to constantly improve people's awareness, as well as the ability to help themselves and each other.

4.2.7 Establishing a national flash flood disaster monitoring and early warning system for communities

The mountainous areas in the north and west of Pakistan are prone to flash floods, so it is necessary to carry out professional monitoring and early warning services for communities in small watersheds to minimize casualties.

(1) It is recommended to carry out investigation and evaluation on flash floods. For residential buildings in hilly areas, the investigation and analysis on flash floods should be carried out, and the dangerous areas of flash floods delimited, to reasonably determine the early warning thresholds of flash floods.

(2) It is recommended to establish flash flood disaster monitoring and early warning system. Pakistan should build a specialized monitoring and early warning platform for flash flood, develop a series of rainstorm and flood analysis models for small watersheds, and determine a technical pattern to realize forecasting and early warning using short-term forecasting, nowcasting and real-time rainfall monitoring data.

(3) It is recommended to establish the transmission mechanism of forecasting and early warning information. Make full use of and upgrade the existing information transmission channels to issue early warning information, configure community early warning facilities and equipment, and send early warning information directly to residents and responsible persons in charge of community's flood disaster prevention.

CamScanner

(4) It is recommended to formulate pre-arranged plans for flash flood disaster prevention at county, township and village levels in hilly areas, and to make family "know-how cards" to enhance local people's awareness of disaster prevention and emergency evacuation capabilities.

4.2.8 Strengthening fundamental research on flood control and DRR

It is a prerequisite to successful flood control and DRR planning, construction management, and operation and maintenance to carry out fundamental research in a down-to-earth manner. The basic research in the mid-term future should be carried out around the key efforts of flood control and DRR in this stage.

(1) It is recommended to strengthen the research on the formation mechanism of extreme weather and climate events, and the prediction technology of objective weather and climate forecasting, improve the meteorological and hydrological forecasting and early warning models for different types of rainstorm floods, and study the forecasting technology of cryosphere melt, glacier melt and glacial lake outbursts.

(2) It is recommended to study the composition characteristics, flood superposition routines and disaster-causing mechanism of different types of floods in the mainstream of the Indus River and its major tributaries. Develop distributed hydrological models adapted to different regional hydrometeorological characteristics, and improve the computational method of rainstorm and flood.

(3) It is recommended to develop the flood control joint operation model of cascade reservoirs and sluices, and optimize and improve the operation and coordination of flood control engineering system. The development scheme of information system to support decision-making on flood regulation in the Indus River Basin should be proposed.

(4) It is recommended to develop the model of soil and water loss in the river basin and the model of sediment transport in the river channel to predict the tendency of riverbed evolution. Develop the prediction model of reservoir sedimentation and water-sediment regulation, study the prevention and control measures of reservoir sedimentation and the systematic treatment scheme in order to reduce its impact on downstream irrigation canals.

CamScanner

4.3 Focuses in the long-term future

With the sustainable development of Pakistan's economy and society, it is necessary to improve structural and non-structural systems for flood control and DRR and implement the construction of major flood control and drainage projects, to further improve the flood control and disaster mitigation capacity of the whole society. In this vein, it is recommended to focus on strengthening the following efforts:

4.3.1 Accelerating the construction of flood control reservoirs in the upper reaches of the Indus River

A multi-channel financing mechanism should be established to gradually promote the construction of flood control reservoirs in the mainstream and major tributaries of the Indus River from the strategic perspective of security of energy, flood control, food and ecology, and in accordance with the principle of optimizing the comprehensive benefits of flood control, power generation, irrigation, water supply and ecology. Eventually, a reservoir cluster will be formed so that it may carry out multi-objective operation in a unified manner, and give full play to its comprehensive benefits through optimized regulation. In the planning and design of reservoir projects, it is necessary to consider the risk of cascade dam failure caused by upstream glacial lake outburst, reserve sediment storage capacity, and set up sediment discharge facilities according to the requirements of optimal regulation of water and sediment, so as to reduce the adverse effects of sediment deposition.

4.3.2 Carrying out the construction of major dike reinforcement and standard upgrading in key areas

Based on the flood control planning of the river basin, it is recommended to comprehensively consider the flood level of the river course and inundation scenarios in the region and set different flood control standards according to the importance of the objects protected by river dikes, to determine dike construction parameters such as crest width and free board accordingly. For some major infrastructures such as railways, large-scale bridges across the river, expressways and other key infrastructures, the foundation elevation and corresponding flood control measures should be defined independently. Existing dikes with frequent

CamScanner

occurrences of dangerous situations recently and serious impacts of potential breaches should be heightened and reinforced. The combination of dikes and roads or constructing roads on the landside dike slope should be adopted to solve the problem of emergency passage in the flood season, so as to facilitate the transportation of emergency materials and the passage of emergency vehicles.

4.3.3 Gradually constructing a water network engineering system in the Indus River Basin

In order to meet the multi-objective needs of flood control, power generation, irrigation, water supply and drainage in the basin, on the basis of the existing layout of rivers, connecting channels, irrigation canals and drainage canals, a water network engineering system planning for the Indus River Basin should be formulated to realize the synergetic integration of the flood control system, irrigation system and drainage system in the basin and regions and the balanced allocation of water resources in space, and to promote the effective utilization of flood water resources by constructing pivotal projects and water system connection projects. The options include the construction of new irrigation canals to convey water into the irrigated areas, lowlands or newly established economic development areas, and the development of new flood diversion channels and drainage canals in the plains on both banks of the Indus River.

4.3.4 Strengthening the construction management of river-related projects

The encroachment of economic and social activities on river floodplains or inappropriate engineering construction is one of the main reasons for the amplification of flood disasters. Following the flood governance philosophy of "providing outlet for flood flow and space for flood storage", the construction management of the projects involving with the river should be strengthened to prevent disorderly encroachment on river courses and flood passage space. Residential buildings within the scope of river management should be gradually moved out of, and the dike rings for farming or other water-blocking structures in farmlands should also be removed as soon as possible. It is recommended that Pakistan government should improve laws, regulations and standards which would be the basis for the examination and approval of

CamScanner

the construction of structures that cross over, intersect with or are adjacent to the river. It is recommended that Pakistan government shoule also establish a flood impact assessment system, in which roads, culverts, and bridges across rivers need to meet the requirements of flood discharge capacity of the river, and those that do not meet the requirements should be rebuilt or upgraded. It is also necessary to develop and utilize remote sensing image recognition technology to assist the construction management of illegal or disorderly development in rivers.

4.3.5 Constructing river regime control and deflection structures for key river sections in the lower reaches of the Indus River

The mainstream of the Indus River has high sediment concentration, and the gradient of the downstream channel is gentle, so the river channel siltation problem is becoming more and more prominent, which may lead to the problems such as poor flood discharge capacity, turbulent flow, unstable shoals and channels, and siltation at the mouth of the estuary. It is necessary to carry out dredging in key river reaches, construct river regime control and deflection projects such as groins and bank revetments to stabilize the river channel, narrow the migration range of the main channel, improve the boundary conditions of the river channel and the flow pattern, reduce the risk of sediment deposition in the riverbed, and ensure the flow capacity of the river channel and stabilize the sediment transport into the sea while preventing the near-bank scour and concave bank scour from endangering the safety of dikes.

4.3.6 Implementing soil and water conservation projects in the upper reaches of the Indus River

It is recommended to implement integrated river basin management and soil and water conservation projects in the small watersheds of the upper reaches of the mainstream and major tributaries of the Indus River to control or reduce slope runoff and water loss and soil erosion, reduce the disaster risks of flash floods and debris flows, reduce reservoir siltation, and reduce sediment transport in the river channel, which is very important for stabilizing the river channel and alleviating the flood control pressure in the middle and lower reaches. The

CamScanner

optional measures include rational planning of land use and development, implementation of forest and grass restoration projects in ecologically fragile areas, strengthening grazing management, construction of check dams, alteration of sloping farmland or terrace farming in mountainous areas.

4.3.7 Continuously promoting the building of emergency rescue forces and emergency response capacity

It is recommended that Pakistan should strengthen the capacity building of professional emergency rescue forces, and enhance the level of regularization, specialization and professionalization, which may be achieved through promoting the standardization and gridding management of grass-roots emergency management, carrying out rescue skills training for social emergency forces, and organizing and implementing categorized and graded evaluations. Communities should conduct emergency relief drills, and provide risk assessment, management consultation, technical maintenance and insurance services. Public education should be systematically conducted regarding disaster prevention, mitigation and relief through various channels and forms, in order to enhance the awareness of risk prevention and the ability of the whole society to perform self-rescue and mutual rescue. It is recommended that Pakistan government should build and improve its national material reserve systems and mechanisms by combining the central and local governments and combining governments and enterprises, and formulate a national material reserves plan to ensure the reserves of grains, emergency materials and other disaster supplies.

4.3.8 Improving strategic response capability for disaster prevention and mitigation to adapt to climate change

Starting from the goal of reducing the risk of abnormal flood disasters, it is recommended that Pakistan should strengthen the research on climate change and its impact, and the disaster-causing mechanism of particularly severe disasters, so as to find out the trend and routines of extreme climate events, flood disaster intensity, occurrence frequency and spatial and temporal distribution. Qualitative and quantitative analysis of the impact of future snow-melting floods and glacial lake outburst, the establishment of service platform for

CamScanner

climate change monitoring, prediction and impact analysis, and the gradual formation of normal service capabilities should be accomplished to support the monitoring of glacial lakes and land-slide dammed lakes in northern mountainous areas and the early warning of GLOF risk. According to the extreme storm flood risk scenarios, the strategies for the Indus River Basin, key regions, key cities, and key flood control and drainage projects should be proposed to cope with the storm floods exceeding design standard.

CamScanner