

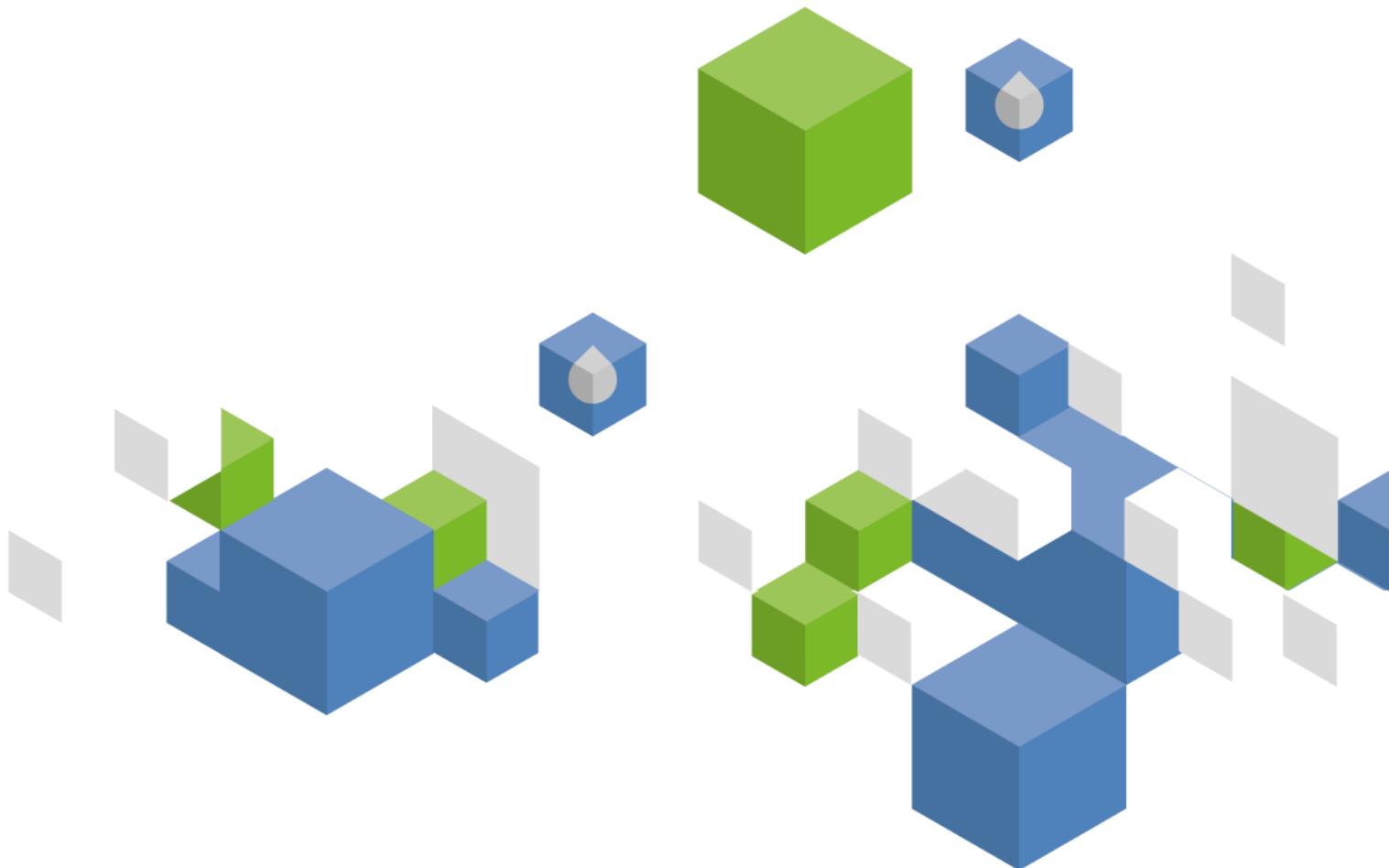


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Indus transboundary river basin

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The transboundary Indus river basin has a total area of 1.12 million km² distributed between Pakistan (47 percent), India (39 percent), China (8 percent) and Afghanistan (6 percent) (Table 1). The Indus river basin stretches from the Himalayan mountains in the north to the dry alluvial plains of Sindh province in Pakistan in the south and finally flows out into the Arabian Sea. In Pakistan, the Indus river basin covers around 520 000 km², or 65 percent of the territory, comprising the whole of the provinces of Punjab and Khyber Pakhtunkhwa and most of the territory of Sindh province and the eastern part of Balochistan. The drainage area lying in India is approximately 440 000 km², nearly 14 percent of the total area of the country, in the States of Jammu and Kashmir, Himachal Pradesh, Punjab, Rajasthan, Haryana and Chandigarh. Only about 14 percent of the total catchment area of the basin lies in China, covering just 1 percent of the area of the country, and Afghanistan, where it accounts for 11 percent of the country's area. Very roughly, at least 300 million people are estimated to live in the Indus basin.

TABLE 1
Country areas in the Indus river basin

Basin	Area		Countries included	Area of country in basin (km ²)	As % of total area of the basin	As % of total area of the country
	km ²	% of Southeast Asia				
Indus	1 120 000	5.4	Pakistan	520 000	47	65
			India	440 000	39	14
			China	88 000	8	1
			Afghanistan	72 000	6	11

Climate

Climate is not uniform over the Indus river basin. It varies from subtropical arid and semi-arid to temperate subhumid on the plains of Sindh and Punjab provinces to alpine in the mountainous highlands of the north. Annual precipitation ranges between 100 and 500 mm in the lowlands to a maximum of 2 000 mm on mountain slopes. Snowfall at higher altitudes (above 2 500 m) accounts for most of the river runoff (Ojeh, 2006).

The Upper Indus river basin is a high mountain region and the mountains limit the intrusion of the monsoon, the influence of which weakens northwestward. Most of the precipitation falls in winter and spring and originates from the west. Monsoonal incursions bring occasional rain to trans-Himalayan areas but, even during summer months, not all precipitation derives from monsoon sources. Climatic variables are strongly influenced by altitude. Northern valley floors are arid with annual precipitation from 100 to 200 mm. Totals increase to 600 mm at 4 400 m, and glaciological studies suggest accumulation rates of 1 500 to 2 000 mm at 5 500 m. Winter precipitation (October to March) is highly spatially correlated across the Upper Indus basin, north and south of the Himalayan divide.

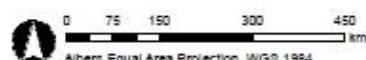
Figure 1
Indus River Basin



Indus river basin

Legend

- | | | |
|-------------------------------|--------------------------------|----------------|
| — International boundary | Lake | ▲ Dam, Barrage |
| - - - Administrative boundary | Intermittent Lake | — River |
| • • • Line of Control | Salt Pan | — Canal |
| @ • Capital, town | Zone of irrigation development | ● River basin |



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From 1961 to 1999 there were significant increases in winter, summer and annual precipitation and significant warming occurred in winter whilst summer showed a cooling trend. These trends will impact upon water resource availability (Fowler and Archer, 2005).

The climate in the Indus plains is arid to semi-arid. In the lower plain December to February is the cold season and mean monthly temperatures vary from 14 to 20 °C. Mean monthly temperatures during March to June vary from 42 to 44 °C. In the upper plain mean temperature ranges from 23 to 49 °C during summer and from 2 to 23 °C during winter. Average annual rainfall on the Indus plains is about 230 mm. On the lower plain, Larkana and Jacobabad areas, on average receive about 90 mm of rainfall annually. On the upper plain, Multan receives 150 mm and Lahore about 510 mm of rain. Because of the hot climate, the evaporation rate is very high and the mean annual evaporation on the lower plain (Nawabshah) is 204 mm while on the upper plain (Sargodha) it is 1 650 mm (WCD, 2000).

WATER RESOURCES

Surface water

The river flows are comprised of glacier melt, snowmelt, rainfall and runoff. Outside the polar regions, the Upper Indus river basin contains the greatest area of perennial glacial ice in the world (22 000 km²); the area of winter snow cover is an order of magnitude greater. The glaciers serve as natural storage reservoirs that provide perennial supplies to the Indus river and some of its tributaries (WCD, 2000). The Indus river system forms a link between two large natural reservoirs, the snow and glaciers in the mountains and the groundwater contained by the alluvium in the Indus plains of the Sindh and Punjab Provinces of Pakistan (Ojeh, 2006).

The Indus river has two main tributaries, the Kabul on the right bank and the Panjnad on the left. The Panjnad is the flow resulting from five main rivers (literally Punjab means “five waters”): the Jhelum and Chenab, known as the western rivers with the Indus river, and the Ravi, Beas and Sutlej, known as the eastern rivers. This division came into effect at the time of settlement of a water dispute between India and Pakistan in 1960. Under this Indus Water Treaty, the following rules apply:

- Western rivers: Pakistan shall receive for unrestricted use all those waters of the western rivers, i.e. Chenab and Jhelum, which is India under obligation to let flow, except for restricted uses, related to domestic use, non-consumptive use, agricultural use and generation of hydroelectric power of which the amounts are set out in the Treaty. Annual flow from China to India in the Indus basin is 181.62 km³ and it is estimated that the flow generated within India is 50.86 km³, resulting in a flow from India to Pakistan in this part of 232.48 km³, of which 170.27 km³ are reserved for Pakistan and 62.21 km³ are available for India.
- Eastern rivers: All the waters of the eastern tributaries of the Indus river originating in India, i.e. the Sutlej, Beas and Ravi rivers taken together, shall be available for unrestricted use by India. Pakistan shall be under an obligation to let flow, and shall not permit any influence with, the waters (while flowing in Pakistan) of any tributary which in its natural course joins the Sutlej Main or Ravi Main before these rivers have finally crossed into Pakistan. The average annual flow in India before crossing the border is estimated at 11.1 km³. All the waters, while flowing in Pakistan, of any tributary which in its natural course joins the Sutlej Main or Ravi Main after these rivers have crossed into Pakistan shall be available for unrestricted use of Pakistan.

All the rivers of the Indus system are perennial (WCD, 2000). Aided by a number of smaller rivers (Swat, Haro, Kunar [Chitral], Tochi, Shah Alam, Naguman, Adezai, Soan, etc.) and streams/Nullahs, these rivers supply water to the entire Indus Basin Irrigation System (NDMA-UNDP, 2010).

The Indus river is the twelfth largest river in the world (Ojeh, 2006) and originates near lake Manasarovar to the north of the Himalayas range on the Kailash Parbat mountain in China at an elevation of 5 500 m. The Indus catchment area is unique in the sense that it contains seven of the world's highest

peaks after Mount Everest. Among these are K2 (8 600 m), Nanga Parbat (8 100 m) and Rakaposhi (7 800 m). The river is 3 200 m long out of which 1 114 m are in India. The river has 27 major tributaries above Guddu barrage. The largest tributary is the Shyoke river (640 km long with a catchment area of 20 160 km²) (NDMA-UNDP, 2010). The flow of the Indus river depends on the season, it decreases during the winter and floods the banks during the monsoons.

The Sutlej river originates in China in Western Tibet in the Kailas mountain range and near the source of the rivers Indus, Ganges and Brahmaputra. The river is 1 536 km long and has a catchment area of 75 369 km² (of which 70 percent is in India). It flows into Pakistan (Punjab) near Ferozepur and eventually joins the Chenab river close to Punjnad barrage. The Sutlej river has eight major tributaries (all except Rohi Nullah join Sutlej river in India). The largest tributary is the Beas river, which is 464 km long and with a catchment area of 9 920 km² (NDMA-UNDP, 2010).

The Ravi river originates in the lesser Himalayas range in India. The river is 880 km long with a catchment area of 24 960 km². It runs almost along the India-Pakistan border. The Ravi river has five major tributaries (Ujh, Bein, Basantar, Deg and Hudiara nullahs [streams]), the upper catchments of which lie in India. The largest tributary is Deg Nullah river, which is 256 km long with a catchment area of 730 km² (NDMA-UNDP, 2010).

The Chenab river is formed at the confluence of the Bhaga and Chandra rivers, which join at a place called Tandi. Its uppermost part is snow covered and forms the northeast part of Himachal Pradesh. From Tandi to Akhnoor the river traverses high mountains. The river is 1 232 km long and the catchment area is 41 760 km². The river enters Pakistan a little over Head Marala with very sharp changes in slope. The river has 12 major tributaries. Doara, Dowara, Halsi, Bhimber, Palku and Budhi join close to Marala. The largest tributary is the 120 km long Palku Nullah, with a catchment area of 1 269 km² (NDMA-UNDP, 2010).

The Jhelum river originates in the Kashmir Valley, about 54 km east of Anant Nag, and is 816 km long with a catchment area of 39 200 km². The river has ten major tributaries, including Neelum/Kishan Ganga (the largest tributary, is 260 km long with a catchment area of 3 968 km²), Kunhar, Poonch and Kanshi (NDMA-UNDP, 2010).

The first record of gauge heights was made on the Indus at Attock in 1848. The next was on Chenab at Alexandria Bridge in 1879. The most important river gauging stations, called the rim-stations, have continuous discharge data from the early 1920s when the Indus Discharge Committee was established for this purpose (WCD, 2000).

Total inflow from China to India in the Indus river basin is estimated at 181.62 km³. Total inflow from Afghanistan to Pakistan in the Indus basin is estimated at 21.5 km³, 15.5 km³ from the Kabul river (of which 10 km³ come from Kunar river, which first enters Afghanistan from Pakistan and then flows back to Pakistan after joining the Kabul river) and 6 km³ from other tributaries (Pansjir, Gomal, Margo, Shamal, Kuram). The mean annual inflow into Pakistan from India through the western tributaries, the Jhelum and the Chenab, considering the Indus Water Treaty, amounts to 170.27 km³. The mean annual natural inflow into Pakistan through the eastern rivers (the Ravi, the Beas and the Sutlej) is estimated at 11.1 km³ but, according to the Treaty, this is reserved for India.

Groundwater

The Indus river basin represents an extensive groundwater aquifer, covering a gross command area of 16.2 million ha. The water table was well below the surface (>30 m) and the aquifer was in a state of hydrological equilibrium before the development of the canal irrigation system. The recharge to aquifer from rivers and rainfall was balanced by outflow and crop evapotranspiration. When the canal irrigation system was introduced, percolation to the aquifer was increased in irrigated areas of the Indus basin resulting in the twin menace of waterlogging and salinity. Although, there are disadvantages in having

a high water table, it was used for irrigation with dug wells and tubewells in the fresh groundwater zone. In 2000, estimated groundwater extraction from the aquifer was almost equal to the recharge in fresh groundwater areas; although the balance between recharge and abstraction is not uniform across the basin (WCD, 2000).

Water quality

Water quality of the Indus river and its tributaries is excellent. Total dissolved solids (TDS) range between 60–374 ppm (parts per million), which is safe for multiple uses (Bhutta, 1999; PWP, 2000). TDS in the upper reaches range between 60 ppm during high-flow to about 200 ppm during low-flow. Water quality deteriorates downstream but remains well within permissible limits, with TDS in the lower reaches of the Indus (at Kotri barrage) ranging from 150 to 374 ppm. TDS of some of the tributaries such as Gomal river at Khajuri, Touchi river at Tangi Post and Zhob river at Sharik Weir range between 400 to 1 250 ppm (IWASRI, 1997).

Indiscriminate and unplanned disposal of effluents (including agricultural drainage water, municipal and industrial wastewater) into rivers, canals and drains is causing deterioration of water quality in the downstream parts. In 1995 around 12.435 km³/year (40 million m³/day) of untreated water were being discharged into water bodies (Ahmad, 2008b). It was estimated that 0.484 and 0.345 km³/year (1.3 and 0.9 million m³/day) of sewage was produced in Karachi and Lahore metropolitan areas respectively and most of it was discharged untreated into water bodies. The polluted water is also being used for drinking in downstream areas, causing numerous water-borne diseases.

The groundwater is marginal to brackish in quality in 60 percent of the Indus Basin Irrigation System's (IBIS) aquifer (Ahmad, 2008a; 2008b). Groundwater quality varies widely, ranging from < 1 000 ppm to > 3 000 ppm. Besides TDS, there are quality concerns regarding sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) (WAPADA 2006).

Use of pesticides and nitrogenous fertilizers is seriously affecting shallow groundwater and entry of effluents into rivers and canals is deteriorating the quality of freshwater. Almost all shallow freshwater is now polluted with agricultural pollutants and sewage (Ahmad, 2008a; Ahmad, 2008b).

Investments in drainage have been significant during the last two decades, though waterlogging still affects large tracts of land. Soil salinity and sodicity also constrain farmers and affect agricultural production. These problems are further exacerbated by poor quality groundwater (Kijne and Kuper, 1995). In fresh groundwater areas, excessive pumping by tubewells leads to mining and reduction of groundwater quality (WRRI, MONA and IIMI, 1999).

In the 1990s waterlogging in the IBIS area was high in the 1990s because of heavy floods, while droughts in the early years of the current decade (2000–2010) resulted in lowering of the water table and in reduction of the waterlogged area. The overall analysis depicts that there is no change in waterlogging. Currently, in the Pakistani part of the basin, the waterlogged and saline areas are around 7 million ha. During the late 1990s most of the SCARP tubewells were abandoned and farmers were provided support to install shallow tubewells (Zaman and Ahmad, 2009).

WATER-RELATED DEVELOPMENTS IN THE BASIN

The 4 000-year-old Indus civilization has its roots in irrigated agriculture. Canal irrigation development began in 1859 with the completion of the Upper Bari Doab Canal (UBDC) from Madhopur Headworks on Ravi river. Until that time, irrigation was undertaken through a network of inundation canals, which were functional only during periods of high river flow. These provided water for kharif (summer) crops and residual soil moisture for rabi (winter) crops. The UBDC was followed by the Sirhind Canal from Rupar Headworks on Sutlej in 1872 and the Sidhnai Canal from Sidhnai barrage on the Ravi river in 1886. The Lower Chenab from Khanki on Chenab in 1892, and Lower Jhelum from Rasul on Jhelum in

1901 followed suit. Lower and Upper Swat, Kabul river and Paharpur Canals in Khyber Pakhtunkhwa (Pakistan) were completed during 1885 to 1914.

In the beginning of the 1900s, it became apparent that the water resources of the individual rivers were not in proportion to the potential irrigable land. The supply from the Ravi river, serving a large area of Bari Doab, was insufficient while Jhelum had a surplus. An innovative solution, the Triple Canal Project, was constructed during 1907-1915. The project linked the Jhelum, Chenab and Ravi rivers, allowing a transfer of surplus Jhelum and Chenab water to the Ravi river. The Triple Canal Project was a landmark in integrated inter-basin water resources management and provided the key concept for the resolution of the Indus waters dispute between India and Pakistan in 1960 with the Indus Water Treaty (IWT).

The Sutlej Valley Project, comprising four barrages and two canals, was completed in 1933, resulting in the development of the unregulated flow resources of the Sutlej river and motivated planning for the Bhakra reservoir. During the same period, the Sukkur barrage and its system of seven canals serving 2.95 million ha in the Lower Indus plain were completed and considered as the first modern hydraulic structure on the downstream Indus river. Haveli and Rangpur from Trimmu Headworks on Chenab in 1939 and Thal Canal from Kalabagh Headworks on Indus were completed in 1947. This comprised the system inherited by Pakistan at the time of its creation in 1947. The IBIS, spread over the flat plains of the Indus Valley, is the largest contiguous irrigation system in the world and is the result of large surface irrigation schemes promoted by the British up to 1947 when their Indian colony was divided into India and Pakistan.

At independence, the irrigation system, conceived originally as a whole, was divided between India and Pakistan without considering the irrigated boundaries. This resulted in an international water dispute in 1948, which was finally resolved by the enforcement of the Indus Water Treaty in 1960 under the aegis of the World Bank.

After Partition, Kotri, Taunsa and Guddu barrages were completed on the Indus river to provide controlled irrigation to areas previously served by inundation canals. The Taunsa barrage was completed in 1958 to divert water to two large areas on the left and right banks of the river making irrigated agriculture possible for about 1.18 million ha of arid landscape in Punjab province (Pakistan). Currently rehabilitation and modernization of the barrage is in progress. Also, three additional inter-river link canals were built before the initiation of the Indus Basin Project. The last inundation canals were connected to weir-controlled supplies in 1962 with the completion of the Guddu barrage on the Indus river.

The Indus Basin Project (IBP) was developed in pursuance of the Indus Water Treaty, including Mangla dam, five barrages, one syphon and eight inter-river link canals, completed during 1960-1971, and Tarbela dam started partial operation in 1975-1976. The two main components of IBP were the major storage reservoirs on Jhelum (Mangla) and Indus (Tarbela) to mitigate the effect of diverting the three eastern rivers by India and to increase agricultural production in the IBIS (Table 2). As part of the implementation schedule of IBP, the Mangla Dam Project was taken up first and completed by 1968. In the meantime, the decision was also taken to go ahead with the Tarbela dam after its re-evaluation by the World Bank and lining up of the additional funding. Consequently construction started in 1968, was substantially completed by 1974, and started partial operation in 1975-1976 (WCD, 2000).

As a result of these extensive developments, Pakistan now possesses the world's largest contiguous irrigation system. It commands a full control equipped area of 14.87 million ha (2008) (36 percent is under Mangla command and 64 percent under Tarbela command (WCD, 2000)) and encompasses the Indus river and its tributaries including three large reservoirs (Tarbela, Mangla, and Chashma), 23 barrages/headworks/siphons, 12 inter-river link canals and 45 canals commands extending for 60 800 km, with communal watercourses, farm channels, and field ditches covering another 1.6 million km to serve over 90 000 farmers' operated watercourses.

TABLE 2
Works completed under the Indus Basin Project (Source: WCD, 2000)

Description of work		Completion year	Between rivers	Command
Construction of link canals	Trimmu -Sidhnai		Chenab-Ravi	Mangla
	Sidhnai-Mailsi		Ravi-Sutlej	
	Mailsi-Bahawal			
	Rasul-Qadirabad		Jhelum-Chenab	
	Qadirabad-Balloki		Chenav-Ravi	
	Balloki Suleimanki II		Ravi-Sutlej	
	Chashma-Jhelum		Indus-Jhelum	
Construction of barrages *	Taunsa-Panjnad		Indus-Chenab	Tarbela
	Sidhnai	1965	Ravi	
Construction of dams	Marala	1968	Chenab	Mangla
	Qadirabad	1967	Chenab	
	Rasul	1967	Jhelum	
	Chashma	1971	Indus	Tarbela
	Mailsi (Siphon)	1965	Under Sutlej	
Remodelling of existing works	Mangla	1968	Jhelum	Mangla
	Tarbela	1976	Indus	
	Chashma (barrage)	1971	Indus	
Ballocki-Suleimanki Link I			Ravi-Sutlej	
Marala-Ravi Link			Chenab-Ravi	Mangla
BRBD Link			Chenab-Ravi	
Ballocki Headworks			Ravi	

* Barrages are constructed to divert river water into canals and the storage capacity is insignificant.

River water in the Indus system is diverted by barrages and weirs into main canals and subsequently branch canals, distributaries and minors. The flow to the farm is delivered by over 107 000 watercourses, which are supplied through outlets (moghas) from the distributaries and minors. The mogha is designed to allow a discharge that self-adjusts to variations in the parent canal. Within the watercourse command (an area ranging from 80 to 280 ha), farmers receive water proportional to their land holding. The entire discharge of the watercourse is given to one farm for a specified period on a seven-day rotation. The rotation schedule, called warabandi, is established by the Provincial Irrigation and Power Department, unless the farmers can reach a mutual agreement.

In Pakistan, more than 95 percent of irrigation is located in the Indus river basin. In 2008, the total area equipped for irrigation throughout Pakistan was estimated at 19.99 million ha. The total water managed area in Pakistan is around 21.20 million ha, and can be divided according to the following classification:

- Full control irrigation schemes cover a total area of 19.27 million ha, of which 14.87 million ha lie within the IBIS and 4.40 million ha outside. The areas outside the IBIS cover minor perennial irrigation schemes, groundwater schemes including tubwells, wells, karezes and springs. They are located in Khyber Pakhtunkhwa and Balochistan.
- Spate irrigation covered a total potential area of 2 million ha in 2004. This area refers to potential spate area, but actual area varies based on flood occurrence and frequency and is around 0.72 million ha in an average year. In Pakistan, these areas are known as Rod Kohi in Khyber Pakhtunkhwa and Punjab, or Bandat in Balochistan, and are often called flood irrigation.
- Flood recession cropping areas covered a total area of 1.21 million ha in 2004. In Pakistan these areas are known as Sailaba, and are often called falling flood irrigation areas. Sailaba cultivation is carried out on extensive tracts of land along the rivers and hill streams subject to annual inundation. The moisture retained in the root zone is used after the flood subsides together with subirrigation owing to the capillary rise of groundwater and any rain.

In 1990, the area equipped for irrigation in Pakistan was estimated at 15.73 million ha and total water managed area was estimated at 16.96 million ha.

The total area equipped for irrigation in the entire Indus river basin is estimated to be around 26.3 million ha, of which Pakistan accounts for approximately 19.08 million ha or 72.7 percent, India for 6.71 million ha or 25.6 percent, Afghanistan for 0.44 million ha or 1.7 percent and China for 0.03 million ha or 0.1 percent. Area actually irrigated is estimated at 24.5 million ha. The equipped area irrigated by surface water accounts for 53 percent while groundwater accounts for 47 percent.

The cropped area in the Indus basin in Pakistan expanded with the increased availability of water from the Tarbela dam. Other factors helped to increase the cropped area: increased numbers of tractors, availability of planting machinery and credit support. A rapid rise in population also encouraged the cultivation of additional areas to meet the growing needs of the population. The major rabi crops in the Tarbela command are wheat, fodder and horticultural crops. Sugarcane also needs irrigation during the rabi season and thus competes for water with rabi crops. There was a significant shift in cropping patterns with the increased availability of water from Tarbela dam. There was a net increase in the cropped area of food grains and cash crops such as wheat, rice, cotton and sugarcane. Consequently, there was a decrease in the cropped area of coarse grains and conventional oilseeds.

In the Indus basin, irrigated agriculture saw an increase in area of 36 percent, 44 percent, 39 percent and 52 percent for wheat, cotton, rice and sugarcane, respectively. The overall increase in the cropped area was around 39 percent (Table 3).

TABLE 3
Cropped area of selected crops in the Indus basin irrigated agriculture in Pakistan (Source: Agricultural statistics of Pakistan, Government of Pakistan, in: WCD, 2000)

Crops	Cropped Area (million ha)					Percent increase 1971-1975 to 1991-1995
	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	
Wheat (rabi)	5.93	6.49	7.24	7.60	8.06	36
Cotton (kharif)	1.92	1.91	2.22	2.53	2.76	44
Rice (kharif)	1.51	1.88	1.98	2.01	2.10	39
Sugarcane (year-round)	0.61	0.76	0.90	0.82	0.93	52
Oilseeds (kharif and rabi)	0.59	0.53	0.41	0.41	0.61	4
All Fruits (year-round)	0.20	0.26	0.36	0.44	0.50	150
Total Area	10.76	11.83	13.11	13.91	14.96	39

Wheat is the leading food grain for human consumption, while its straw is used as a source of cheap roughage for livestock feed. The increase in the area under sugarcane, in particular, is the result of the availability of additional irrigation water from the Tarbela reservoir as it is a crop that demands a lot of irrigation. Other factors that contributed towards this increase were the development of the sugarcane industry and the road infrastructure, both of which provided the necessary linkages for growth (WCD, 2000).

In 2008, total harvested irrigated cropped area in Pakistan was estimated at 21.45 million ha, most of it in the IBIS. The major irrigated crops in the country are wheat, rice, sugarcane, cotton and fodder. These crops comprise almost 78 percent of the total harvested area, or 16.6 million ha, with wheat covering 7.3 million ha, rice 2.5 million ha, sugarcane 1.2 million ha, cotton 3.1 million ha and fodder 2.5 million ha (GoP, 2008).

When the IBIS was developed, the drainage needs were initially minimal. Water tables were deep and irrigation water supplies were too low to generate much groundwater recharge and surface water losses. Whatever little drainage was required, could readily be accommodated by the existing natural drainage. The drainage needs, however, increased over time as more irrigation water was diverted and the water table rose to harmful levels causing waterlogging and salinity. The drainage systems mostly have been developed over the last 30-40 years (Bhutta and Smedema, 2005).

Total water withdrawal in the Indus river basin is estimated at 299 km³, of which Pakistan accounts for approximately 63 percent, India for 36 percent, Afghanistan for 1 percent, and China for barely 0.04 percent. Irrigation withdrawal accounts for 278 km³, or 93 percent of the total. Surface water and groundwater account for 52 percent and 48 percent of total withdrawals in the Indus river basin respectively.

Most summer rains are not available for crop production or recharge to groundwater because of rapid runoff from torrential showers.

In the Pakistani part of the basin, in 2005, total dam capacity was estimated at 23.36 km³. Currently, there are three large hydropower dams and 50 smaller dams (more than 15 m high), while 11 smaller dams are under construction. The designed live storage capacity of the three large hydropower dams in the Indus river basin is 22.98 km³ (Tarbela 11.96 km³, Raised Mangla 10.15 km³, which includes recent raising of 3.58 km³, and Chashma 0.87 km³). The current live storage capacity of these three large hydropower dams is 17.89 km³, representing an overall loss of storage of 22 percent (World Bank, 2005).

Pakistan can barely store 30 days of water in the IBIS. Each km³ of storage capacity lost means one km³/year less water that can be supplied with a given level of reliability. There is an urgent need for storage just to replace capacity that has been lost because of sedimentation. Given the high silt loads from the young Himalayas, two large reservoirs are silting rapidly. In 2008, because of the raising of the Mangla dam, the loss resulting from sedimentation was recovered (World Bank, 2005). The designed live storage capacity of 50 small dams is 0.383 km³. Information related to sedimentation and loss of live storage of small dams is not available. Therefore, it was assumed that on average 25 percent of the live storage of these small dams has been lost as a result of sedimentation, leading to a current live storage capacity of these small dams of 0.287 km³.

There are more than 1 600 mini dams (less than 15 m high), which were constructed for small-scale irrigation purposes, but the capacity of these mini dams is low as a mini dam is normally constructed for an individual farmer. Information on the live storage capacity of mini dams is not available and it is negligible compared to small dams. According to certain estimates, the total designed capacity of these mini dams would be in the order of 0.036 km³.

The Pakistani part of the Indus river basin has a hydroelectric potential of about 50 000 MW. Its main gorge, between the Skardu and Tarbela, has a potential of almost 30 000 MW. These include Bashan (4 500 MW), Disso (3 700 MW), Banjo (5 200 MW), Thicket (1 043 MW), Paten (1 172 MW), Racicot (670 MW), Yuba (710 MW), Hugo (1 000 MW), Tunas (625), and Sakardu or Kithara (possibly 4 000 to 15 000 MW). Almost 20 000 MW potential is available on various sites on the rivers: Swat, Jhelum, Neelam, Punch and Kumar (Qazilbash, 2005).

In 2010, India had six large dams in the Indus basin, with a total dam capacity of 18.6 km³. Bhakra and Nangal dams are on the Sutlej river, Pandoh and Pong dams are on the Beas river and Salal and Baglihar are on the Chenab river.

Table 4 shows the large dams in the Indus river basin.

TABLE 4
Large dams in the Indus river basin (2010)

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m ³)	Main use *
India	Bhakra	Nangal	Sutlej	1963	226	9 620	I, H
	Nangal	Nangal	Sutlej	1954	29	20	I, H
	Pandoh	Mandi	Beas	1977	76	41	I, H
	Pong	Mukenan	Beas	1974	133	8 570	I, H
	Salal	Reasi	Chenab	1986	113	285	H
	Baglihar		Chenab	2008		33	H
Total						18 589	
Pakistan	Mangla	Mangla	Jhelum	1968	116	10 150**	I, H
	Tarbela	Ghazi	Indus	1976	137	11 960	I, H
	Chashma (barrage)	Mianwali	Indus	1971	-	870	I
Total						22 980	
TOTAL						41 569	

* I = irrigation; H = Hydropower

**

Includes recent raising of 3.58 km³

Table 5 shows the barrages in the Indus river basin.

TABLE 5
Barrages in the Indus river basin (Source: NDMA-UNDP, 2010)

Country	Name	River basin	Year	Main use
India	Rupar	Sutlej	-	Irrigation
	Harike	Sutlej	-	Irrigation
	Ferozepur	Sutlej	-	Irrigation
	Madhopur Headwork	Ravi	-	Irrigation
Pakistan	Sulemanki & Islam	Sutlej	-	Irrigation
	Balloki & Sidhnai	Ravi	1965	Irrigation
	Marala	Chenab	1968	Irrigation
	Khanki	Chenab	-	Irrigation
	Qadirabad	Chenab	1967	Irrigation
	Trimmu	Chenab	-	Irrigation
	Punjab	Chenab	-	Irrigation
	Rasul	Jhelum	1967	Irrigation
	Kalabagh	Indus	-	Irrigation
	Chashma	Indus	1971	Irrigation
	Taunsa	Indus	1958	Irrigation
	Guddu	Indus	1962	Irrigation
	Sukkur	Indus	-	Irrigation
	Kotri	Indus	1955	Irrigation
	Mailsi (Siphon)	Under Sutlej	1965	Irrigation

TRANSBOUNDARY WATER ISSUES

In 1948 India unilaterally cut off supplies to Pakistan canals originating from the headworks located on the eastern rivers of Ravi and Sutlej thereby asserting its right to the waters of three eastern rivers (Ravi, Beas and Sutlej). Besides causing a serious setback to the national economy, this would have seriously disrupted Pakistan's water resources development plans. Therefore, right from its creation, the country had to accord the highest priority to the resolution of water disputes involving India. After protracted negotiations, the dispute was finally resolved and culminated in the signing of the Indus Water Treaty in 1960 (WCD, 2000).

Details of the flows under this Treaty are given in the section: Water resources. This Treaty helped to resolve the issues between the two countries and allowed Pakistan to invest extensively in the Indus Basin Project (IBP) during the 1960s to construct a network of canals and barrages to divert waters from the western rivers to the command of the eastern rivers as replacement works. However, in the last few

years Pakistan has objected to India's development of hydropower projects on the western rivers, Chenab and Jhelum.

Baglihar dam, constructed in the Chenab in Jammu and Kashmir and completed in 2008, has been the source of continuing disputes between India and Pakistan. After construction began in 1999, Pakistan claimed that the design parameters of the Baglihar project violated the Indus Water Treaty. Finally, the World Bank held that India had not violated the Indus Water Treaty and said that the dam could be completed with slight modifications in design and without any impact on the 450 MW power component. The World Bank determined that India should reduce the freeboard in the height of the dam from 4.5 m to 3 m. India had offered to do this before Pakistan referred the dispute to the World Bank. Another objection by Pakistan was related to the width of the pondage that India could maintain in the run-of-the river project. India claimed a pondage of 37.5 million m³. This was reduced by a neutral expert to 32.58 million m³, while upholding India's methodology of calculation and rejecting Pakistan's suggestion of a pondage of 6.22 million m³ (The Hindus, 2007; Press Information Bureau, 2008).

Table 6 lists the main historical events in the Indus river basin.

TABLE 6
Chronology of major events in the Indus river basin

Year	Plans/projects/treaties/conflicts	Countries, agencies involved	Main aspects
1859	Completion of the Upper Bari Doab Canal	British Indian Colony	Canal irrigation development began to provide water for <i>kharif</i> (summer) crops and residual soil moisture for <i>rabi</i> (winter) crops
1872	Completion of the Sirhind Canal	British Indian Colony	From Rupar Headworks on Sutlej
1886	Completion of the Sidhnai Canal	British Indian Colony	From Sidhnai barrage on Ravi
1982	Completion of the Lower Chenab Canal	British Indian Colony	From Khanki on Chenab
1901	Lower Jhelum Canal	British Indian Colony	From Rasul on Jhelum
1885-1914	Lower and Upper Swat, Kabul river and Paharpur Canals in Khyber Pakhtunkhwa (Pakistan)	British Indian Colony	Completed during 1885 to 1914
1907-1915	Triple Canal Project	British Indian Colony	Constructed during 1907-1915. The project linked the Jhelum, Chenab and Ravi rivers, allowing a transfer of surplus Jhelum and Chenab water to the Ravi.
1920	Indus Discharged Committee was established	British Indian Colony	Formed to record discharge data
1933	Sutlej Valley Project	British Indian Colony	Completed in 1933. Four barrages and two canals, resulting in the development of the unregulated flow resources of the Sutlej river and motivated planning for the Bhakra reservoir (now in India).
1930's	Sukkur barrage and its system of seven canals	British Indian Colony	Completed. Considered to be the first modern hydraulic structure on the downstream Indus river
1939	Completion of Haveli and Rangpur Canal	British Indian Colony	From Trimmu Headworks on Chenab
1947	Completion of the Thal Canal	British Indian Colony	From Kalabagh Headworks on Indus
1947	British Indian Colony divided into India and Pakistan		
1948	Water disputes between India and Pakistan	India and Pakistan	India unilaterally cut off supplies to Pakistan canals originating from the head-works located on the eastern rivers of Ravi and Sutlej
1954	Completion of the Nangal dam	India	On the Sutlej river
1955	Completion of the Kotri barrage	Pakistan	Was completed on the Indus river to provide controlled irrigation to areas previously served by inundation canals (as Taunsa and Guddu)
1958	Completion of the Taunsa barrage	Pakistan	Completed to divert water to two large areas on the left and right banks of the river

TABLE 6 (*continued*)

Chronology of major events in the Indus river basin

Year	Plans/projects/treaties/conflicts	Countries, agencies involved	Main aspects
1960	Indus Water Treaty (IWT)	World Bank, India, Pakistan	Resolved water disputes. Under the IWT all water of the eastern rivers shall be available for the unrestricted use of India. The three western rivers and all water while flowing in Pakistan of any tributary, which in its natural course joins the Sutlej main or the Ravi main after these rivers have crossed into Pakistan, shall be available for the unrestricted use of Pakistan (see "Water resources" section for details).
1962	Completion of the Guddu barrage	Pakistan	On Indus river
1963	Completion of the Bhakra dam	India	On the Sutlej river
1960-76	Indus Basin Project	Pakistan	Developed in pursuance of the IWT, including Mangla dam, five barrages (including Chashma reservoir), one syphon and eight inter-river link canals, completed during 1960-1971, and Tarbela dam started partial operation in 1975-1976.
1974	Completion of the Pong dam	India	On the Beas river
1977	Completion of the Pandoh dam	India	On the Beas river
1986	Completion of the Salal dam	India	On the Chenab river
2008	Completion of the Baglihar dam	India, Pakistan, World Bank	On the Chenab river. Disputes since the construction begun in 1999 between India and Pakistan. The World Bank finally authorized the construction

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