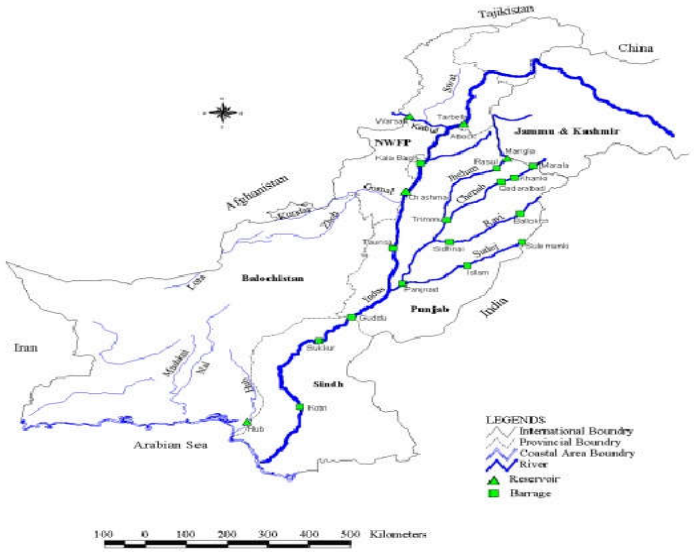
Irrigation Engineering Lab Report # 1
"Indus Basin Irrigation System"

Submitted To:

Engr. Usman Ali

Submitted By:

Abid Ali
(2011-civil-110) Sec-B



CIVIL ENGINEERING DEPARTMENT,
UNIVERSITY of ENGINEERING & TECHNOLOGY,
LAHORE

Irrigation System of Pakistan

Brief History of Irrigation System of Pakistan:

Controlled year round irrigation began in 1859 with the completion of the Upper Bari Doab Canal (UBDC) from Madhopur Headworks (now in India) 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 some soil moisture for rabi (winter) crops.

The last inundation canals were connected to weir controlled supplies in 1962 with the completion of Guddu Barrage on Indus River. UBDC was followed by Sirhind Canal from Rupar Headworks on Sutlej in 1872 (also in India) and Sidhnai Canal from Sidhnai Barrage on Ravi 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 NWFP were completed between 1885 to 1914. By the turn of the century, it became apparent that the water resources of the individual rivers were not in proportion to the potential irrigable lands. Ravi River, serving a large area of Bari Doab, was deficient in supply while Jhelum had a surplus. An innovative solution was developed in the form of the Triple Canal Project, 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.

The Triple Canal Project as a land-mark in integrated inter basin water resources management and also provided the key concept for the resolution of the Indus Waters Dispute between India and Pakistan in 1960.

The Sutlej Valley Project, comprising of 4 barrages and 2 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 (now in India).

During the same period, the Sukkur Barrage and its system of 7 canals serving 2.95 million hectares of land in Lower Indus were completed. 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.

At independence, the irrigation system, conceived originally as a whole, was divided between India and Pakistan without regard to irrigated boundaries. This resulted in the creation of an international water dispute in 1948, which was finally resolved by the enforcement of Indus Waters Treaty in 1960 under aegis of the World Bank. The treaty assigned the three eastern rivers (Ravi, Beas, Sutlej) to India, with an estimated total mean annual flow of 33 million acre

feet (MAF) and the three western rivers (Indus, Jhelum, Chenab) to Pakistan with a transfer of irrigation supplies from the western rivers to areas in Pakistan formerly served by the eastern rivers as well as some development potential to compensate for the perpetual loss of the eastern waters. The Indus Basin Project including Mangla Dam, 5 barrages, 1 syphon and 8 inter-river link canals, was completed during 1960-71, while Tarbela Dam started partial operation in 1975-76.

After partition, Kotri, Taunsa and Guddu Barrages were completed on the Indus River to provide controlled irrigation to areas previously served by inundation canals. Also, three additional inter-river link canals were built prior to the initiation of Indus Basin Project.

Irrigation System of Pakistan, its Components and Historical Development:

LAND USE IN PAKISTAN

	CATEGORY	AREA (MH)	AREA (MA)
1.	Geographical Area (total area)	79.3	196.0
2.	Area suitable for agriculture	31.2	77.1
3.	Irrigated + Barani	22.1	54.5
4.	Irrigated area by all sources	18.0	44.5
5.	Additional area that can be brought under irrigated agriculture	9.2	22.6

Indus Basin Treaty 1960:

World Bank, under the Treaty, does have an obligation to appoint a neutral expert, there is no legal mechanism whereby the findings of this expert can be implemented forcefully by the World Bank against the wishes of one of the Parties. Of course, the terms of the Treaty are binding on the signatories and, therefore, the decision of the neutral expert also falls in this category; but then India has violated the terms of the Treaty itself – so, who will ensure that it accepts the findings of the neutral expert..

Obviously India had done its homework on the Indus Water Treaty far better than us. By going for a neutral expert through the World Bank when the Baglihar Dam project is almost complete, we are not going to get much. Even if the expert rules in our favour, who will make India undo the Dam physically? Certainly not the World Bank, which has quite correctly stated that it is not a guarantor of the Indus Water Treaty of 1960.2 So it is strange to find the sovereign state of Pakistan having surrendered the rights to the use of its three Eastern rivers (Beas, Sutlej, Ravi) in return for the rights over the waters of the three Western rivers (Indus, Jhelum, Chenab),

with no international guarantees to stop India from eventually seeking to deny Pakistan access to all its river waters.

Although the issue came to a head in 2003 with Pakistan demanding that India stop the illegal construction of the Dam, Pakistan has been raising the Baglihar issue with India since May 1992 when India first supplied it with information regarding the Dam. Pakistan raised objections in August 1992 and since then the issue has been raised at the various meetings of the Indus Waters Commission (IWC) and through exchange of letters (see a chronology of events on the issue in the Annexure). But Indian intransigence on this issue has resulted in the present near-conflictual situation. India has also tried to enmesh the issue with the issue of Kashmiris getting access to sufficient electricity, whereas the two are not linked at all.

The Indus Water Treaty does allow India the right to hydroelectric power generation from the Western rivers but only by run-off river installations without affecting the volume and direction of water. What is clearly not allowed is building storage capacities on the Western rivers, which directly impede the flow of the waters (Article III (4). In order to safeguard against interference with the flows of these rivers by the upper riparian (India) plant designs have to conform to criteria laid down in Annexure D of the Treaty.

At the last meeting between Pakistan and India to resolve the issue, Pakistan sought satisfaction on five major points of concern to it:

- That the project design should be based on low-level weir since the run of the river projects do not require a 'high head' of 475 feet.
- That the calculations of 'pondage' and 'firm power' in the design were inconsistent with the Indus Water Treaty, while the level of 'intake' in the project design was low and contravened the Treaty.
- According to the Treaty requirements, the design should be based on 'un-gated' spillways. The Indian design was contrary to the Treaty requirements. India had to also ensure that gates were at the highest level as provided for in the Treaty.
- The Treaty criteria need to be fulfilled for the provision of calculations and justification of 'free board'.
- Arrangements needed to be made to monitor and inspect the site at the time of plugging of the low-level tunnel.

The Indians maintained their posture that the Treaty did not restrict the construction of a high dam and that the 'pondage', 'firm power' and the level of intake and 'free board' being developed by India were premised on sound techno-economic considerations. In fact India evaded the issue of whether all these points of concern raised by Pakistan were contrary to the Treaty, and refused to respond to Pakistani objections on the basic design. Pakistan's basic argument remains that the Treaty permitted construction only of a 'run of the river plant' on the Chenab and not a high dam of 475 feet.

In the light of the total lack of a satisfactory response from India on this crucial Baglihar Dam issue, Pakistan finally approached the World Bank to appoint a neutral expert, although many in Pakistan feel this is too late to do much good since India has announced that it will continue to complete the project.

Additionally, India has also shown intransigence on other related water issues coming under the purview of the Indus Waters Treaty. For instance, the Indians are pursuing the Kishanganga hydroelectric power project, as well as maintaining the stalemate on the Wullar Barrage. The former project is nearing completion with a 22-km tunnel to divert the waters of the Neelum River to Wullar Lake. The Neelum is an integral part of the river Jhelum – again one of the three Western rivers – and, therefore, the Kishan ganga project also contravenes the Indus Waters Treaty because it impacts the flow of the waters of the Western rivers to Pakistan. Not only will the flow of the water be affected but also Pakistan's prior rights for its proposed 969 mw Neelum-Jhelum hydropower project in Azad Kashmir.

Indian lack of concern over observing international Treaty commitments has surfaced once again with an announcement of three more dam projects in Occupied Kashmir.4 The new projects are again on the Western rivers – the Uri-II project is on the Jhelum river in Baramulla district, and Pakal Dul and Burser, both on the Marusundar, a tributary of the Chenab river in Doda district. The Indian Ministry of Power has already approved these projects and it seems apparent that India may well be headed towards reneging on the Indus Water Treaty totally if Pakistan asserts its rights under the Treaty.

All in all, the Indus Waters issues not only highlight the very real security dimension of the Kashmir issue for Pakistan but also Indian efforts to pit the Kashmiris against Pakistan on the false claims that Pakistan wishes to deny the former access to hydroelectricity from the waters that flow through Kashmir. Unless Pakistan exposes Indian designs and the absurdity of its claims to the Kashmiris, Pakistan will find itself not only moving towards desertification of the rich plains of the Punjab but also may find itself facing an increasingly hostile Kashmiri population across the LOC.

THE WATER APPORTIONMENT ACCORD – 1991

The Water Apportionment Accord was agreed upon on March 16, 1991 at Karachi in a meeting of the Chief Ministers of the four provinces along with several provincial representatives. The accord allocates the following share to provinces:

KEY NOTE

In 1991, an agreement to share waters of the Indus River was reached between the four provinces of Pakistan in the form of the Water Apportionment Accord (WAA). This accord is based on both, the existing and future water needs of the four provinces.

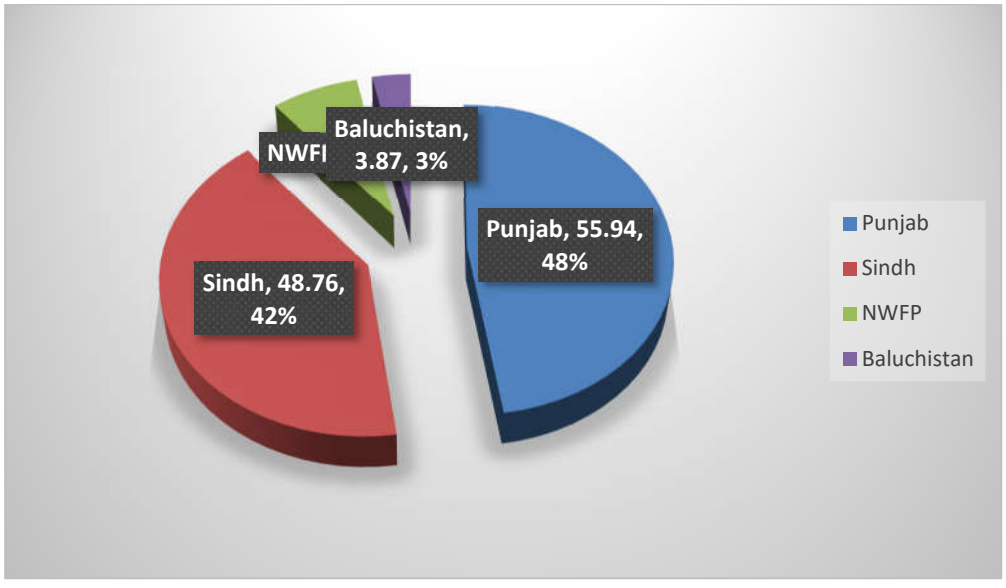
The Chief Ministers of the four provinces, in a unique demonstration of mutual cooperation and national spirit, resolved the long outstanding dispute, which had brought water development in the country to a grinding halt.

THE PURPOSE OF THE WATER ACCORD

Surface water developments after the final commissioning of the Tarbela Dam Project in 1977, were almost stalled due to the non-resolution of the inter-provincial water dispute. The country underwent a one and a half decade long crisis related to irrigation supplies and hydropower generation before reaching consensus. Load-shedding and irregular agriculture produce was observed during this period. An inter-provincial agreement became essential to solve the longstanding dispute of canal water uses, shares in the river supplies and surplus flows in the form of floods, etc. An agreement called the "Apportionment of the Water of the Indus River System between Provinces" was arrived upon, which had two important features. It protected the existing uses of canal water in each province.

i. It apportions the balance of river supplies, including flood surpluses and future storages among the provinces.

Province	Kharif (MAF)	Rabi(MAF)	Total (MAF)
Punjab	37.07	18.87	55.94
Sindh	33.94	14.82	48.76
NWFP	3.84+1.8	2.3+1.2	5.78+3
Baluchistan	2.85	1.02	3.87
Total	77.34	37.01	114.35



- The NWFP/ Baluchistan projects, under execution, were provided their authorized quota of water as existing uses.
- Balance river supplies (including flood supplies and future storages) was to be distributed as below:

Punjab	Sindh	Balochistan	NWFP	Total
37%	37%	12%	14%	**100**%

Industrial and Urban Water supplies for Metropolitan City, for which there were sanctioned allocations, was to be accorded priority.

- The need for storages, wherever feasible on the Indus and other rivers was admitted and recognized by the participants for planned future agricultural development.
- The need for certain minimum escapage to sea, below Kotri, to check sea intrusion was recognized. Sindh held the view, that the optimum level was 10 MAF, which was discussed at length, while other studies indicated lower/high figures. It was, therefore, decided that further studies would be undertaken to establish the minimal escapage needs downstream Kotri.
- There would be no restrictions on the provinces to undertake new projects within their agreed shares.
- No restrictions were placed on small schemes not exceeding 5,000 acres above elevation of 1200 ft. SPD.
- No restrictions were placed on developing irrigation uses in the Kurram / Gomal / Kohat basins, so long as these do not adversely affect the existing uses on these rivers.
- There were no restrictions on Balochistan, to develop the water resources of the Indus right bank tributaries, flowing through its areas.
- The requirements of LBOD would be met out of the flood supplies in accordance with the agreed sharing formula.
- For the implementation of this accord, the need to establish an Indus River System Authority was recognized and accepted. It was to have headquarters at Lahore and representation from the entire four provinces.
- (i) The system-wise allocation would be worked out separately, on ten daily basis and attached with the agreement as part and parcel of it.(ii) The record of actual average system uses for the period 1977-82, would form the guide line for developing a future regulation pattern. These ten daily uses would be adjusted pro-rata to correspond to the indicated seasonal allocations of the different canal systems and would form the basis for sharing shortages and surpluses on all Pakistan basis.

(iii) The existing reservoirs would be operated with priority for the irrigation uses of the Provinces

(iv) The provinces would have the freedom within their allocations to modify system-wise and period-wise uses.

(v) All efforts would be made to avoid wastages. Any surpluses may be used by another province, but this would not establish any rights to such uses.

REPLACEMENT PLAN WORKS CONSTRUCTED AS A RESULT OF INDUS WATER TREATY 1960

Storage Reservoirs:

Structures	River	Gross Storage Capacity (MAF)
Mangla	Jehlum	5.89
Chashma	Indus	0.7
Tarbela	Indus	11.0

Barrages:

Barrage Name	River Name	Flood of Record (Cusecs)	Design Flood (Cusecs)	Length of Barrage (Feet)
Sidhnai	Ravi	167,000	167,000	712
Siphon	Sutlej	427,000	429,000	1601
Qadirabad	Chenab	912,000	900,000	3373
Rasool	Jehlum	876,000	850,000	3209
Chashma	Indus	1,176,000	950,000	3556
Marala	Chenab	1,023,000	1,100,000	4472

Link Canals:

Canal Name	Capacity (Cusecs)	Length (Miles)	Excavation (MYD^3)
Trimu-Sidhnai	11,000	44	21
Sidhnai-Mailsi	10,100	62	31.3
Mailsi-Bahawal	3,900	10	2.4
Rasool-Qadirabad	19,000	30	38.3
Qadirabad-Balloki	18,600	80	80.3
L.C.C Feeder	4,100	20	8
Balloki-Sulemanki	6,500	39	20.5
Chashma-Jehlum	21,700	63	118.5
Taunsa-Pajnad	12,000	38	22.5

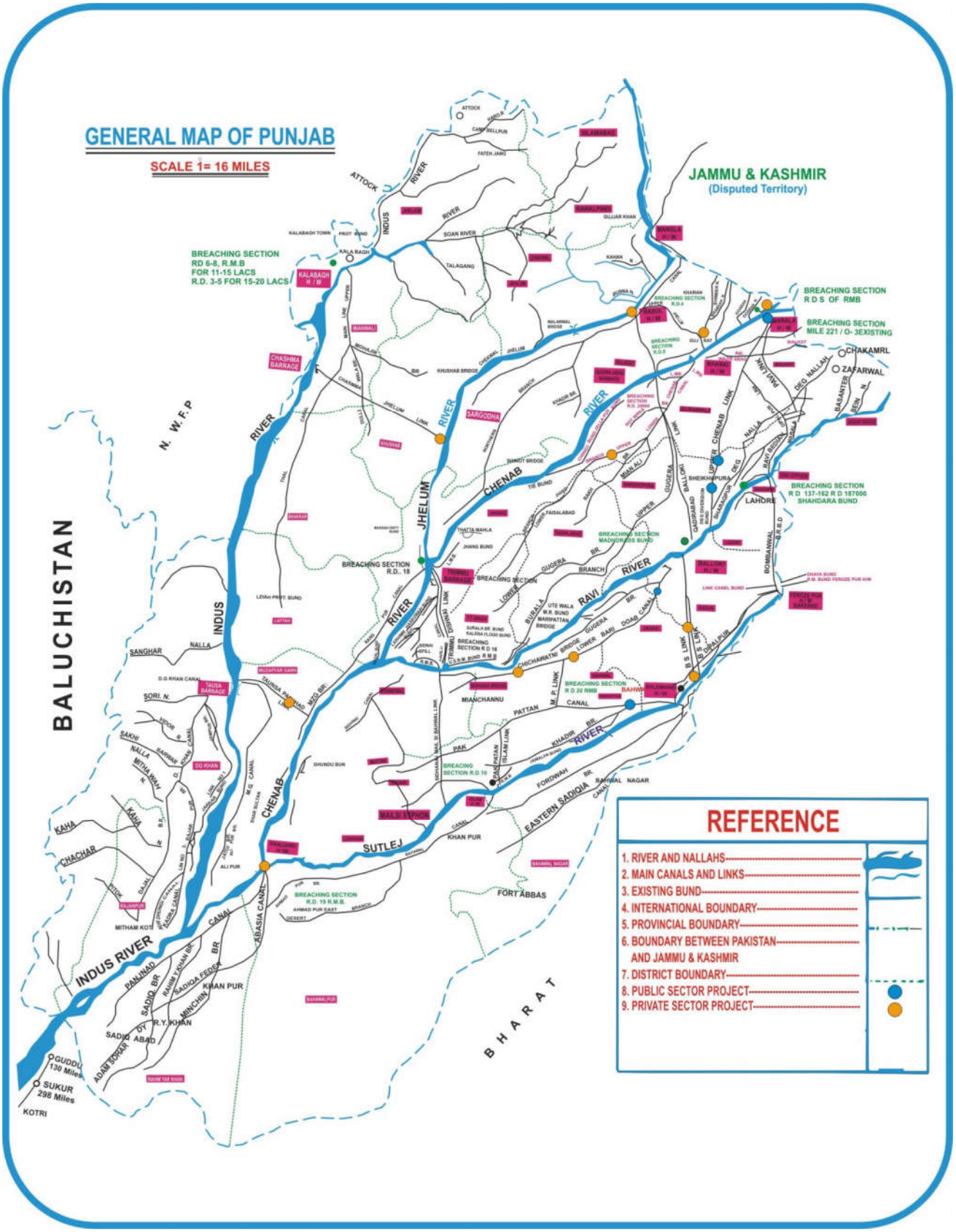


Figure 1: Schematic Sketch of Rivers, Structures and off taking canals

Indus Basin Irrigation System with Respect to Different Views:

1. PHYSIOGRAPHY

Pakistan is located in the north-west part of the Indo-Pakistan sub continent about in the middle of the SouthAsian region. it is surrounded by the neighbouring countries of Iran, Afghanistan, China and India with a coast on Arabian Sea. It lies wholly in the temperate zone between latitudes 24E and 37E North and longitudes 61E and 75E East. Total area is 310,400 square mile (803,936 Km2) of which one per cent comprises water areas. It is a land of varied landscapes ranging from perpetually snow apped peaks of Himalayan Range like the Karakoram, K-2 elevation 28,265 ft. (8,615 m) to lush green canal irrigated areas and the hot dry deserts of Sindh and Baluchistan where summer temperatures can exceed 120E F (49E C). Physiographically the country can be divided into three regions :

- Mountainous north and north-west 241,647 Km2;
- Table lands of Balochistan 242,683 Km2 and
- Vast alluvial plain of the Indus River and tributaries 319,605 Km2.

2. LAND RESOURCES

From the total land area of 197 million acres (79.61 million ha) about 79 million acres (31.9 million ha) or 40 per cent is cultivable but only 21.59 million ha or 27 per cent is cultivated. Annual cropped area is 56.64 million acres (22.93 million ha) or 29 per cent due to limitations of water supply. Out of this two-thirds is irrigated and one third depends on rain (called Barani), The canal irrigated system covers 81 per cent of the irrigated area while the rest depends on tubewells, open wells and flood irrigation called sailaba. Quality of land for agricultural purposes is classified as in Table .

{PRIVATE }Sr. No.	Class	Area per cent
i.	Very good agricultural land	30.7
ii.	Good agricultural land	42.9
iii	Moderate agricultural land	5.7
iv.	Poor agricultural land	3.5
v.	Good grazing land	-
vi.	Poor grazing land	-
vii.	Agricultural non-productive land	15.5
viii.	Miscellaneous	1.7
		100.0

3. CLIMATE AND RAINFALL

Pakistan is located entirely in the temperate zone and within the monsoon belt the position of high mountain ranges in the north keeps her climate generally as arid and semi-arid, tropical and sub-tropical. There are four distinct climatic seasons :

- Cold, moderate widespread rainfall December to March.
- Extremely hot and dry, April to June.
- Hot and humid, scattered rainfall, July to September.
- Cool and dry, October and November.

Normal periods for the two major crops grown are "Rabi" (meaning "spring") from October to March and "Kharif" (meaning "fall) from April to September. The crops are named by the harvesting season.

Temperatures in the plains and most other cultivable areas allow for year round cropping, rarely dropping to freezing point. The summer are very hot with average maximum temperatures of 38EC and 40EC from May to July over greater part of the Indus Plain. Temperatures of the order of 49EC are not rare. The highest maximum temperature of 53EC recorded at Jacobabad in Upper Sindh ranks amongst the world' highest. In the mountains of the north, summers are generally cool, the temperature varying appreciably with differences in elevation, exposure, etc. The plains experience frequent dust storms which are usually followed by thunder showers. The winters can be fairly cool with average maximum day temperature of 20EC during December and January and minimum temperatures generally between 2.2EC to 5EC (36EF to 41EF) but occasionally approaching freezing point. The lowest minimum temperature of -26EC was recorded at Misgar on 9 February 1949. The climate along the coast is not so hot in the summer and is mild in the winter due to the moderating effect of the sea. The total annual pan evaporation in the Indus Plains ranges from around 50 inches (1,270 mm) in North-east Punjab to 110 inches (2,800) in Sindh. Evaporation is generally highest in May and lowest in January with 65 to 75 per cent occurring in April-September months. Distribution of rainfall in Pakistan is such that the heaviest annual rainfall is on the Southern slopes of Himalayas which reduces rapidly toward the south. Southern Punjab and Northern Sindh get the lowest amount of rain which increases again toward the coastal area. Mean annual rainfall figures from north to south are given in

{PRIVATE } Place	Mean Annual Rainfall
Jacobabad	110 mm
Hyderabad	178 mm
Multan	187 mm
Karachi	168 mm
Quetta	261 mm
Lahore	629 mm
Islamabad	1142 mm
Muree	1789 mm

The seasonal distribution of rainfall is strongly influenced by the monsoon circulation. Starting in June or early July, it lasts till September and causes 70 per cent of the rainfall in the country varying from 48 inches (1220 mm) in the sub-mountainous northern areas to 5 inches (127 mm) in the arid regions of Sindh and Baluchistan in the south. The balance 30 per cent of rainfall in winter comes during December to March and is more wide-spread. It

is caused by western disturbances and is predominant over parts of Baluchistan and North-west Frontier Province NWFP) which have mediterranean climate. The quantity and seasonal distribution of rain fall is normally insufficient for agricultural development in most of the populated areas.

4. POPULATION AND SIZE OF HOLDINGS

The population of Pakistan in July, 1998 was 130.58 million and is projected to increase to 150 million by the turn of the century. Majority of the population, (about 74 percent) lives in rural areas, subsists on agricultural occupations and contributes 25 percent of the gross domestic product. Agricultural exports generate major share of the total foreign exchange earnings of Pakistan. The country is divided into four main administrative units called provinces. These are Baluchistan, Sindh, North West Frontier Province (NWFP) and Punjab. Baluchistan has the least population with largest area while Punjab has the biggest population and the most fertile farm lands. The pattern of farm land holdings is such that 81 percent of farms are under 5 ha in area and 93 percent under 10 ha. Detailed farm size distribution is given in Table 3.

{PRIVATE }Farm Size (ha)	Number	Area (Million ha)	Area Cultivated (Million ha)
Upto 0.5	678538	0.193	0.18
0.5 - 1.0	689233	0.510	0.47
1.0 - 2.0	1036286	1.447	1.33
2.0 - 3.0	841295	1.974	1.81
3.0 - 5.0	857387	3.309	2.97
5.0 - 10.0	623110	4.134	3.55
10.0 - 20.0	237929	3.033	2.42
20.0 - 60.0	91831	2.614	1.84
61.0 & above	15354	1.935	1.04
Total	5070963	19.149	15.61

5. SOILS

The soils of the Indus Plains are basically river alluvial deposits calcareous nature several hundred feet deep. The soil texture ranges from coarse to fine with 85 percent in the moderately coarse to moderately fine categories, mostly suitable for irrigated agriculture. The medium size of soil gradually reduces downstream so that heavier texture is more common in Sindh than in Punjab. The alluvial plains of the Indus extended 1,287 Km from the foothills in the north to the Arabian Sea. The width of this plain at its widest point is 563 Km and at its narrowest point it is more than 161 Km.

The physical properties of the soil are generally favourable for agriculture. The pH value generally ranges from 8 to 8.50.Nitrogen, phosphorus and organic matter are normally low with potassium usually in ample supply. Use of fertilizers is common in the country. Annually around 2 million nutrient tons of fertilizers are used. The nutrients consumption per hectare is 51.2 Kg nitrogen, 15.1 Kg phosphate and 0.9 Kg potash. The fertilizer usage in irrigated area is higher and on the average 104, 76, 57 and 12 nutrients Kg/ha in Punjab, Sindh, NWFP and Baluchistan are applied respectively. The average fertilizers consumption in the country in 1989 was 86 Kg/ha. The problem of salinity had grown serious until attention was paid to drainage. Position has improved since 1960 in areas where tubewells were installed for groundwater drainage and supplementary irrigation. Surface and root zone salinity was aggravated by the practice of canal irrigation since the l at e nineteenth century without much attention to surface and sub-surface drainage. In the hot and arid climate the capability rise of groundwater in areas with salty soils, carries the salts upward to the surface of the root zone.Evaporation of water leaves layers of salt at or close to surface affecting agricultural production. The practice of underwatering or spreading the available surface irrigation supplies over too wide areas, also aggravates the position. Leaving un-irrigated fallow plots also increases salinity in such areas.

6. WATER RESOURCES

6. SURFACE WATERS

The total renewable water resources consist of rainfall and river inflow. Total average annual rainfall is estimated to give 40 million acre ft. (49,300 million m3) with about 30,800 million m2 falling on the culturable canal command area, an average of about 8.25 inches (210 mm). Total average annual inflow of rivers is 172,200 million.

Rivers serving the Indus Plains are the Indus and its principal tributaries the Kabul, the Jhelum, the Chenab, the Ravi and the Sutlej. According to the Indus Water Treaty 1960, Pakistan is entitled to the full use of the Western Rivers comprising the Indus, the Jhelum and the Chenab while the supplies of the Eastern Rivers the Ravi. Sutlej and the Beas are reserved for India. These rivers have low flow season from November to February and start rising in spring and early summer with melting of snow in Himalayas and rise further with the onset of monsoons in June to attain peak flow in July or August.

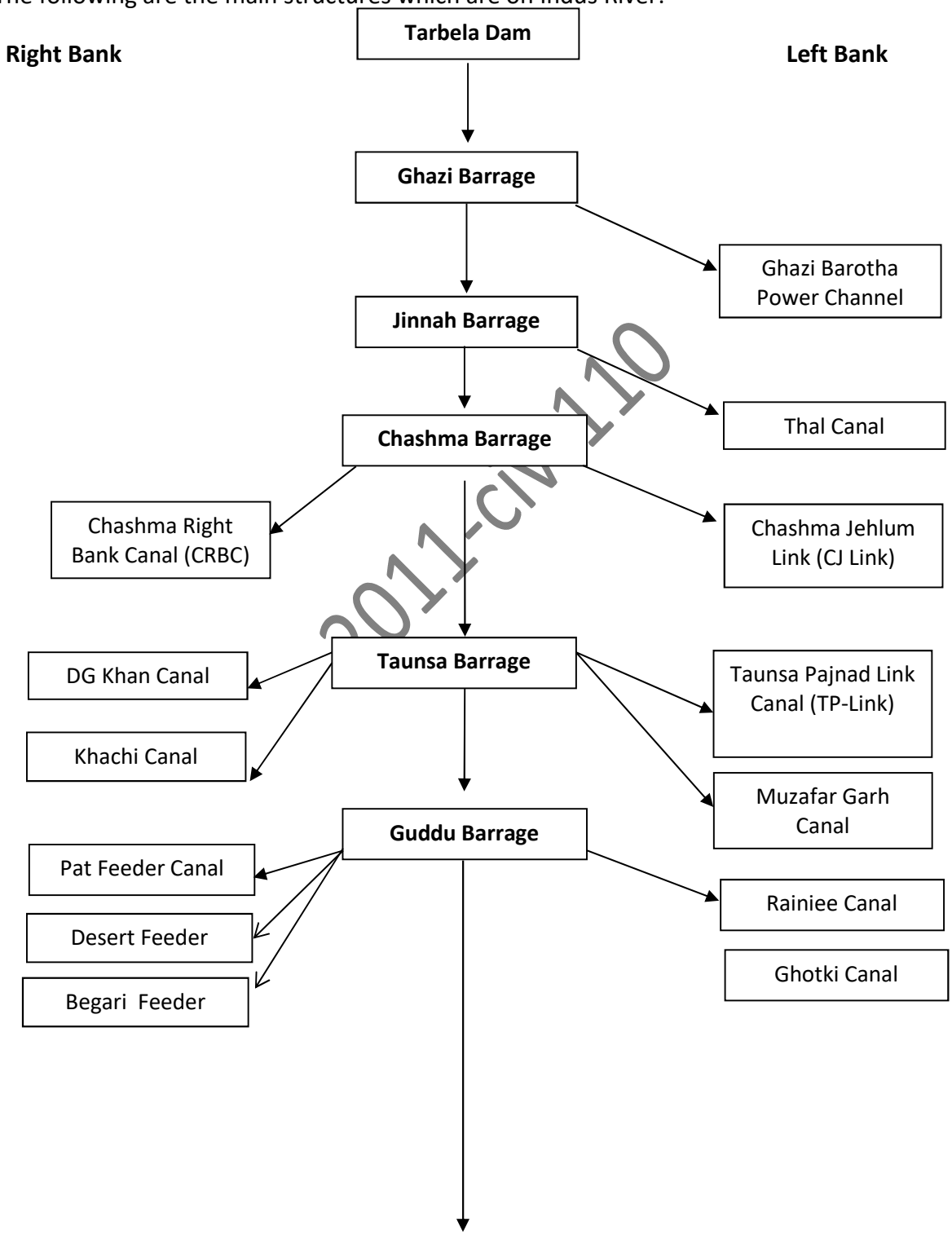
Although there is significant variation in volume of flow from year to year, the Indus River System has high degree of natural regulation, generally at tributable to a large component of snow and glacier melt. Natural regulation ratios measured as the ratio of minimum annual flow to average annual flow are; the Indus, 70 percent;the Jhelum, 58 percent; the Chenab, 70 percent and total system, 68 percent. As a thumb rule it is seldom economical to attempt to raise the regulation ratio of a river to more than 70 percent by use of reservoirs. Therefore the annual regulation rates of the Indus River, and the absence of large reservoir sites, indicate that there is little practical likelihood of use of surface reservoirs to carry over water from high flow to low flow years, and excessive flood flows will continue to go to the sea. However, reservoir storage for transfer of water from the summer high flow season to the winter low flow season will continue to be essential element in water management. The chemical quality of water in the rivers of Pakistan is excellent for irrigation, drinking or industrial purposes. Concentration of total dissolved solids at the rim stations range from below 100 ppm during high flows to about 200 ppm during low flows. In the lower Indus also the dissolved solids range from 150 to 350 ppm only. The suspended sediment in major rivers goes up to 10,000 ppm during high floods and reduces to only a few ppm during low water season. It is estimated that 430 million m3 of sediment enters the Indus basin and about 185 million m3 passes out to the delta. This leaves a balance of 245 million m3 in the reservoirs, rivers and irrigation channels annually. Agro-based economy of the country is dependent on sustainable water resources. The task of uplifting of the economy in water sector is being achieved through Consecutive Five Years Plans. In the recent Plan (Ninth Five Year Plan 1998-2003), it is planned to shift from the tradition, to measure production per unit area to productivity per unit of water. The irrigation system was

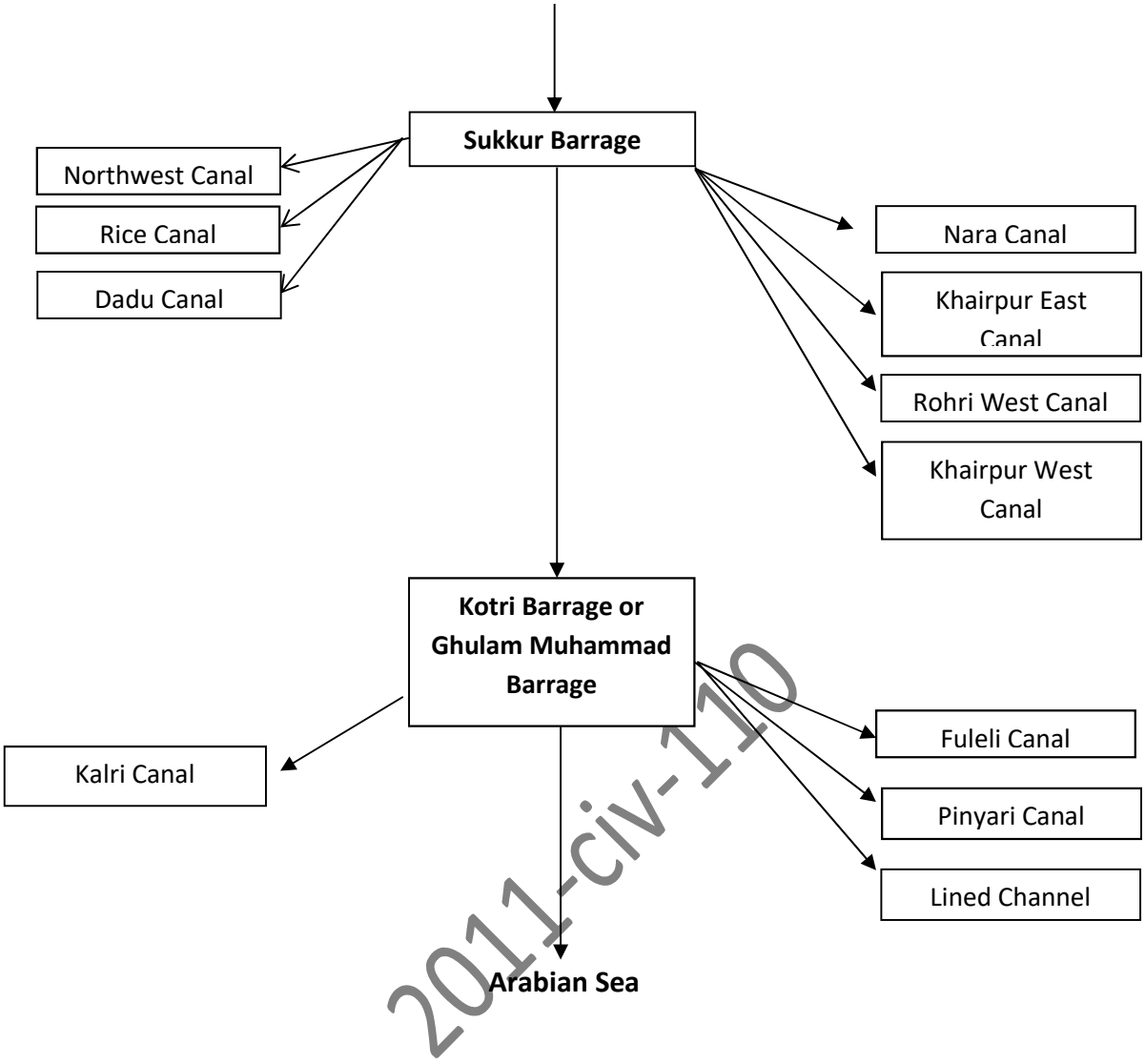
developed to spread run off river water over as large area as possible. No doubt it is quite difficult to shift over this system to demand oriented system, but certain strategies have to be introduced to bring it closer to the demand based system. The primary changes include construction of additional storage and changing the delivery system to regulatory system to overcome existing climatic based scenario. With a large arable land base of 79 million acres of which only about 35 million acres are canal commanded,Pakistan still has the potential of bringing several million acres of virgin land under irrigation. Important impediment in the way of this development is insufficient control over flood water of the rivers. With virtually no limit on availability of land, it is unfortunate to willingly let large quantities of Indus water go waste the sea. In post-Tarbela 18 years, an annual average of over 38 million acre feet (MAF) scaped below Kotri; after adjustment of future abstractions outside Indus Basin, this could still be around 32 MAF. Out of this, an average of over 26 MAF per year could be effectively controlled and efficient utilized to bring about prosperity to millions, particularly in backward areas of Pakistan through national water resources development approach. Water development approach at national level was initially conceived in late 1980's, but a serious impediment in its way was non-resolution of Inter-provincial water dispute. To this effect an accord on "Apportionment of the Waters of the Indus River System between Provinces" was signed on March 21, 1991. After careful determination of average surplus flows during the flood period as per Water Apportionment Accord (WAA) about 12 MAF of additional water was allocated to four Provinces for priority irrigation development. Taking into account all the above factors, a 25-year (1995-2020) National Water Resources Development Programme (NWRDP) has been formulated. It is based on the concept of national approach to tackle the threatening water shortages and anticipated large increases in power tariff due to predominance of thermal power. NWRDP would be an overall package comprising 25 remodelling/ new irrigation schemes in various provinces to benefit an area of over 13 million acres (in equivalent new area terms it would be over 7.6 million acres). To provide assured supplies to the new schemes as well as make up for the loss of capacity for on-line storage, three (3) multipurpose reservoir projects (Basha, Munda and kalabagh) with live capacity of 12.3 MAF would also be constructed.

Salient Features of Barrages & Off Taking Canals in Pakistan Irrigation System:

Structures on Indus River:

The following are the main structures which are on Indus River:




Sukkur Barrage
Northwest Canal
Rice Canal
Dadu Canal
Nara Canal
Khairpur East Canal
Rohri West Canal
Khairpur West Canal
Kotri Barrage or Ghulam Muhammad Barrage
Kalri Canal
Fuleli Canal
Pinyari Canal
Lined Channel
Arabian Sea

1. Tarbela Dam:

Salient features/Principal data of main components of Tarbela Dam

Type	Earth & Rock Fill Dam
Maximum Height above river Bed	465 ft.
Crest Elevation	1565 ft.
Length of Crest (Main Dam)	9000 ft.

Reservoir

Length	60 miles
Maximum Depth	450 ft.
Area	60,000 acres
Maximum Conservation	1550 ft.
Minimum Operation Level	1300 ft.
Design Gross Storage	11.3 MAF
Existing Gross Storage	9.00 MAF
Design Live Storage	7.3 MAF
Surface Area	100 Sq. miles

Spillways:

Service Spillway:

Capacity	650,000 cusecs	(18,405 cumecs)
No. of Gates	7 (Seven)	
Size of Gate	50 ft. Wide & 61 ft. high	(15.24x18.60 meters)

Auxiliary Spillway:

Capacity	850,000 cusecs	(24,070 cumecs)
No. of Gates	9 (Nine)	
Size of Gates	50 ft. wide & 61 ft. high	(15.24x18.60 meters)

2. Ghazi Barrage:

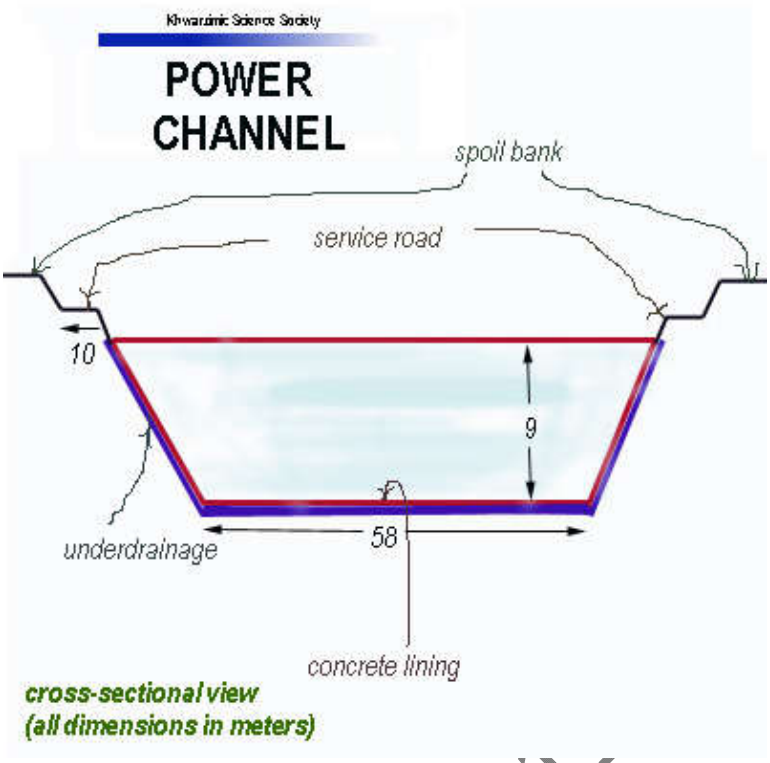
Salient Features of Ghazi Barrage:

Location	6 miles D/S of Tarbela Dam near Ghazi
Purpose	Power generation
Max. Flood capacity.	500,000 cusecs
Number of Bays	20
Design Discharge.	35,000-60,000 cusecs
Total storage capacity	0.18 MAF
Bed width.	350 ft.
Side slopes.	1:1.5
Bed slope.	1:15,000
Generating capacity.	1450 M.W
Gross head.	250 ft.
Rated head.	225 ft.
Crest Level	1070 ft

Canals Off taking from Ghazi Barrage:

i. Ghazi Barotha Power Channel:

Design flow	1,600 cumecs
Longitudinal slope	1V: 2H
Length	51,906 m
Full supply depth	9 m
Bed width	58.4 m
Side slope	IV: 2H
Lining thickness	135 mm



3. Jinnah Barrage or Kalabagh Headwork:

Salient Features of Jinnah Barrage are:

Location	Kalabagh, Distt. Mianwali, on River Indus
Year of construction	1946
Design Discharge.	9,50,000 cusecs
Recorded Discharge	8,61,965
Length	3871 ft
No. of bays.	42
Width of each bay.	60 ft
Maximum flood Level (U/S)	692,05 (SPD)
Maximum flood Level (D/S)	691,25 (SPD)
Pond Level	694

Canals Off taking from Jinnah Barrage:

i. Thal Canal:

Districts	Bhakkar, Khushab, Mianwali and Layyah
Design Discharge	7500 Cusecs
Area being Irrigated	1637,103

4. Chashma Barrage:

Salient Features of Chashma Barrage are:

Max. Design discharge.	11,00,000 cusecs
Total width between abutments.	3,556 ft.
No. of bays.	52
Width of each bay.	60 ft.
Year of construction	1971
Total designed with drawl for the canals.	26,700 cusecs.
Location	Near District Mianwali

Canals Off taking from Chashma Barrage:

i. Chashma-Jehlum Link Canal (CJ Link Canal):

Length	64 Miles
Bed Width	380 ft.
Side Slope	2.5:1 & 2:1
Design Discharge	21,700 Cusecs
Design Depth	14 ft.
Bed Slope	1:10,000
Service Road	25 ft.
Structures	36 Nos.
Acquired Land	10,780 Acres
Contract Cost	210 Million Rupees
Commencement	11th January, 1967
Updated as on	23 June, 2011

ii. Chashma Right Bank Canal (CRBC):

Cultivable Command Area	606,000 Acres /245,240 Hectares		
K.P.K	366,000 Acres /148,115 Hectares		
Punjab	240000 Acres /97,125 Hectares		
Length of Canal	**170 Miles/274 KMs**		
K.P.K	106 Miles/171 KMs		
Punjab	64 Miles/103 KMs		
Distributaries			
Nos/Length	72 Nos 666 Miles/ 1065 KMs		
K.P.K	42 Nos 391 Miles /625 KMs		
Punjab	30 Nos 275 Miles /440 KMs		
Stage-I	13 Nos 141 Miles/227 KMs		
Stage-II	15 Nos 105 Miles/168 KMs		
Stage-III(K.P.K)	14 Nos 145 Miles/230 KMs		
Punjab	30 Nos 275 Miles /440 KMs		
Flood Carrier Channel			
	Nos	Length in (Ft.)	Disch: in (Cusecs)
Stage-II	22	7,270,516	140,800
Stage-III	27	898,834	459,000
Total	67	1,888,885	748,960
	475.70 KMs. 21,208 Cumecs		
Discharge Capacity	4879 Cusecs/ 138.16 Cumecs		
K.P.K	3045 Cusecs/86.23 Cumecs		
Punjab	1,834 Cusecs/ 51.93 Cumecs		

5. Taunsa Barrage:

Salient Features of Taunsa Barrage are:

Location	18 miles downstream of Chasma Barrage
Design Discharge	750,000 cusecs
No. of Bays	53
Width of each bay	60 ft
Total withdrawal for the canals	36501 cusecs

Canals Off taking from Taunsa Barrage:

i. Taunsa Pajnad Link Canal:

Length	38 miles
Width	266 ft
Depth	12 ft
Authorized full supply	12000 Cusecs
Full supply level	444 ft
Crest of head regulator	443 (SPD)
Gross commanded area	21, 50,000 acres
Cultural commanded area	20, 00,000 acres

ii. Muzafar Garh Canal:

Length	102 miles
Width	205 ft
Depth	10 ft
Authorized full supply	7300 Cusecs
Gross commanded area	7, 78,000 acres
Cultural commanded area	6, 97,675 acres

iii. DG Khan Canal:

Length	100 miles
Width	275 ft
Depth	12 ft
Authorized full supply	8800 Cusecs
Full supply level	444 ft
Gross commanded area	8, 05,000 acres
Cultural commanded area	7, 35,898 acres

iv. Kachi Canal:

Total Length of Canal	500 km
Length in Punjab	300 km(Lined)
Length in Balochistan	200 Km (Unlined)
Districts of Punjab	Muzafargarh, Rajanpur
Districts of Balochistan	Dera Bughti, NaseerAbad, Bolan and Jhal Magsi

6. Guddu Barrage:

Salient Features of Guddu Barrage are:

River	Indus
Max. design discharge.	12,00,000 cusecs
Total width between abutments.	444.5 ft.
No. of bays.	64
Width of each bay.	60 ft.
Year of construction	1962

Canals Off Taking From Guddu Barrage:

i. Ghotki Feeder canals

ii. Begari Feeder canals

iii. Desert feeder canals

iv. Pat Feeder canals

7. Sukkur Barrage:

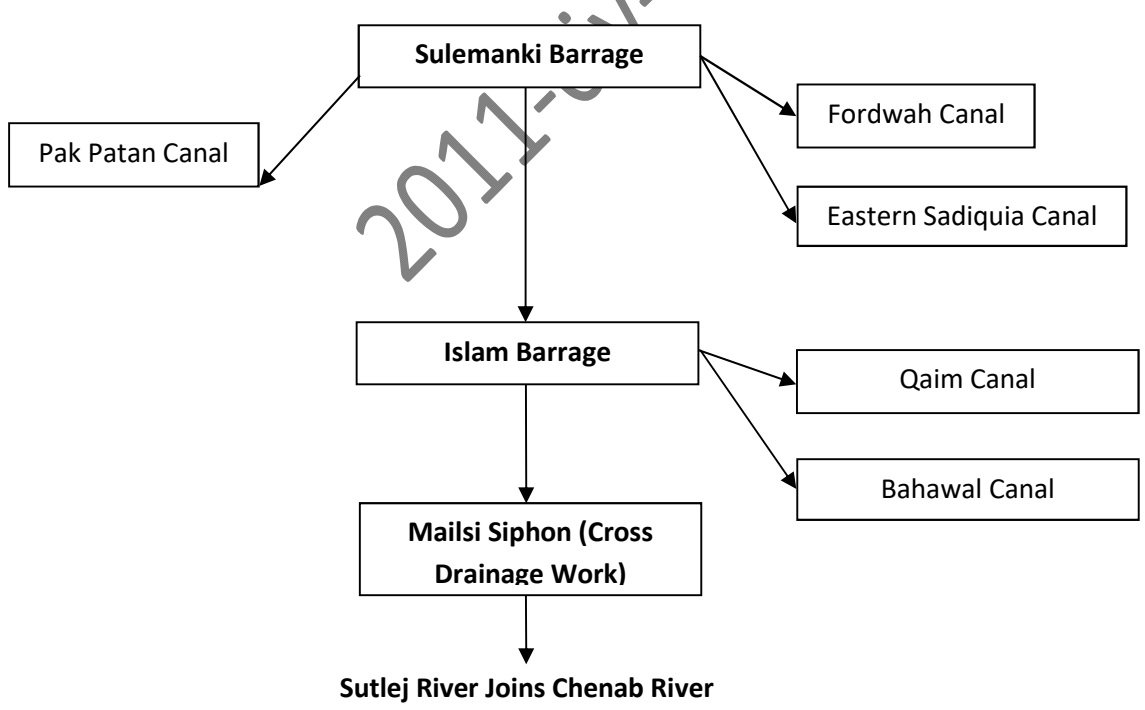
8. Salient Features of Sukkur Barrage are:

River	Indus
Max. design discharge.	15, 00,000 cusecs
Total width between abutments.	4725 ft.
No. of bays.	54
Width of each bay.	60 ft.
Year of construction	1932
Total designed with drawl for the canals.	47530 cusecs.

Canals off Taking from Sukkur Barrage:

i. Rice Canal
ii. Dadu Canal
iii. Northwest Canal
iv. Nara Canal
v. Khairpur East Canal
vi. Rohri West Canal
vii. Khairpur West Canal

Structures on Sutlej River:



1. Sulemanki Barrage:

Location.	Sutlej
Max. Design discharge.	3, 50, 000 cusecs
Recorded discharge	5, 98, 872 cusecs
Total width between abutments.	2,223 ft.
No. of bays.	15
Width of each bay.	40 ft.
Year of construction	1926
Maximum flood level on U/S	572 (SPD)
Maximum flood level on D/S	569 (SPD)
Pond level	569

Canals off taking From Sulemanki Barrage:

i. Pakpatan Canal:

Length	136 miles
Width	140 ft
Depth	12 ft
Authorized full supply	6600 Cs
Full supply level	567 ft
Crest of head regulator	559 ft
Gross commanded area	17, 67,800 Acres
Cultural commanded area	12, 57,815 Acres

ii. Fordwah Canal:

Length	9 miles
Width	154 ft
Depth	8 ft
Authorized full supply	3400 Cusecs
Full supply level	567 ft
Crest of head regulator	561 ft
Gross commanded area	4, 64,600 acres
Cultural commanded area	4, 25,903 acres

iii. Eastern Sadiquia Canal:

Length	48 miles
Width	160 ft
Depth	10 ft
Authorized full supply	4900 Cusecs
Full supply level	567 ft
Crest of head regulator	559 ft
Gross commanded area	11, 34,500 Acres
Cultural commanded area	9, 47,135 Acres

2. Islam Barrage:

Location.	Ravi
Max. Design discharge.	3, 88, 000 cusecs
Recorded discharge	4, 92, 581 cusecs
Total width between abutments.	1,621 ft.
No. of bays	29
Width of each bay.	-----
Year of construction	1927
Maximum flood level on U/S	457 (SPD)
Maximum flood level on D/S	454 (SPD)
Pond level	455

Canals off Taking from Islam Barrage:

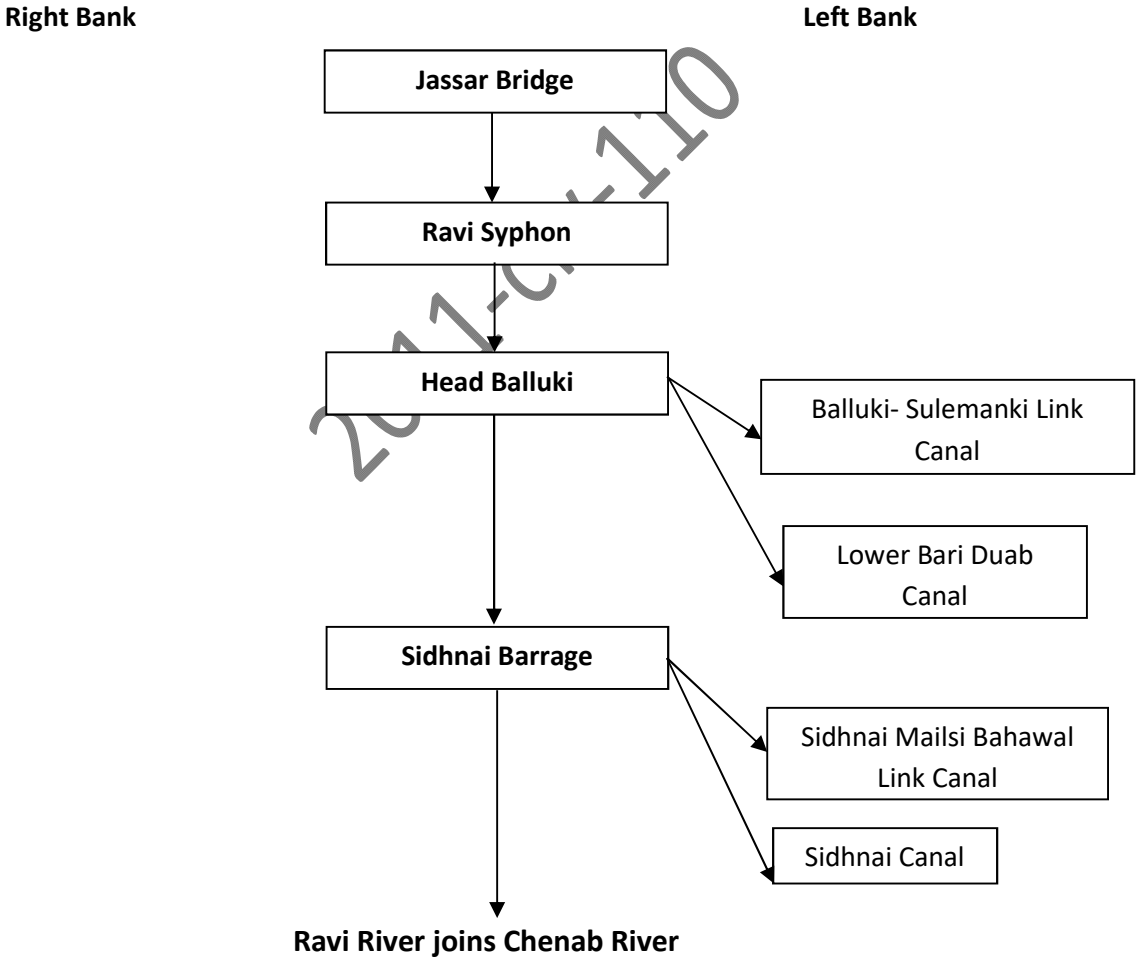
i. Qaim Canal:

Length	6 miles
Width	34 ft
Depth	9 ft
Authorized full supply	600 Cs
Full supply level	453 ft
Crest of head regulator	445 ft
Gross commanded area	45200 acres
Cultural commanded area	42375 acres

ii. Bahawal Canal:

Length	47 miles
Width	138 ft
Depth	11 ft
Authorized full supply	5400 Cusecs
Full supply level	453 ft
Crest of head regulator	445 ft
Gross commanded area	7,90,800 acres
Cultural commanded area	657999 acres

Structures on Ravi River:



1. Head Balluki:

Location.	Ravi
Max. Design discharge.	2, 25 000 cusecs
Recorded discharge	2, 76, 000 cusecs
Total width between abutments.	1646.5 ft.
No. of bays.	35
Width of each bay.	40 ft.
Year of construction	1965
Maximum flood level on U/S	638 (SPD)
Maximum flood level on D/S	635 (SPD)
Pond level	633 (SPD)

Canals off Taking from Head Balluki:

i. Balluki-Sulemanki Link Canal:

Length	39 miles
Width	300 ft
Depth	13ft
Authorized full supply	6500 Cusecs
Full supply level	630 (SDP)
Crest of head regulator	——

ii. Lower Bari Doab Canal (LBDC)

Length	132 miles
Width	202 ft
Depth	10 ft
Authorized full supply	7000 Cusecs
Full supply level	633 ft
Crest of head regulator	627 ft
Gross commanded area	18, 22,200 acres
Cultural commanded area	14, 71,444 acres

2. Sidhnai Barrage:

Location.	Ravi
Max. Design discharge.	1, 67, 000 cusecs
Recorded discharge	2, 44, 000 cusecs
Total width between abutments.	712 ft
No. of bays.	15
Width of each bay.	40 ft.
Year of construction	1965
Maximum flood level on U/S	476 (SPD)
Maximum flood level on D/S	470 (SPD)
Pond level	467 (SPD)

Canals off taking from Sidhnai Barrage:

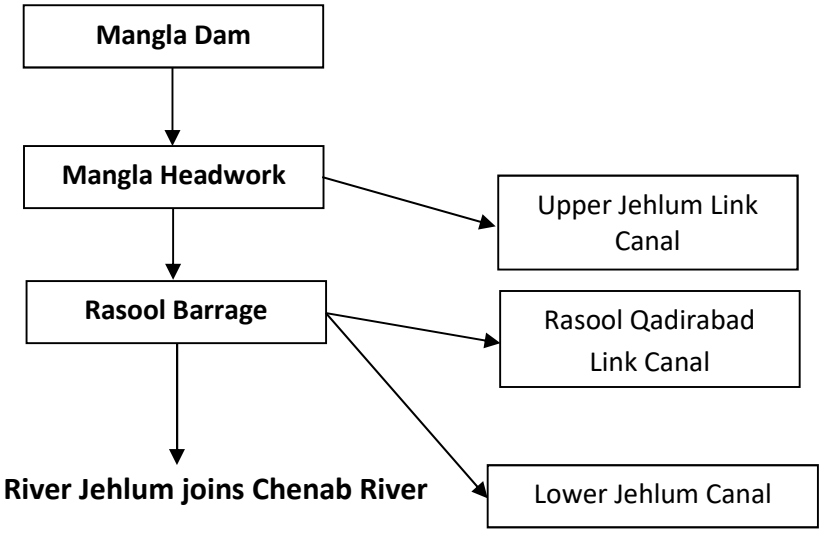
i. Sidhnai Canal:

Length	32 miles
Width	148 ft
Depth	8.7 ft
Authorized full supply	4500 Cusecs
Full supply level	463 (SPD)
Crest of head regulator	458 (SPD)
Gross commanded area	---------
Cultural commanded area	---------

ii. Sidhnai Mailsi Bahawal Link Canal (SMB Link):

Length	62miles
Width	230 ft
Depth	18 ft
Authorized full supply	10100 Cusecs
Full supply level	465 (SPD)
Crest of head regulator	465 (SPD)

Structures on River Jehlum:



1. Mangla Dam:

Reservoir	Crest level of embankments;	El. 1234 ft. SPD
Crest length	8,400 ft.	
Main Spillway		
	Type	Submerged Orifice
	Elevation of cill	El. 1086 ft.
	Capacity at El 1202	0.87 ml.cu.ft. per sec.
	Capacity at El 1228	1.10 ml.cu.ft. per sec.
Emergency Spillway		
	Type	Weir
	Control	Erodible Bund
	Elevation of Erodible Bund	El. 1216 ft.
	Width of Weir	500 ft.
	Capacity at El 1228	0.23 million cubic feet per sec.
Tunnels		
	Number	5
	Internal Diameter	30 ft., 31ft., and 26 ft.
Power Station		
	Number of Sets	10 of 100 MW each
	Total Capacity	1000 MW

2. Rasool Barrage:

Location.	Jhelum
Max. Design discharge.	850, 000 cusecs
Recorded Discharge	9, 52, 170 cusecs
Total width between abutments.	3,209 ft.
No. of bays.	42
Width of each bay.	60 ft.
Year of construction	1967
Pond Level	719 (SPD)
Maximum flood level on U/S	723 (SPD)
Maximum flood level on D/S	718 (SPD)

Canals Off taking from Rasool Barrage:

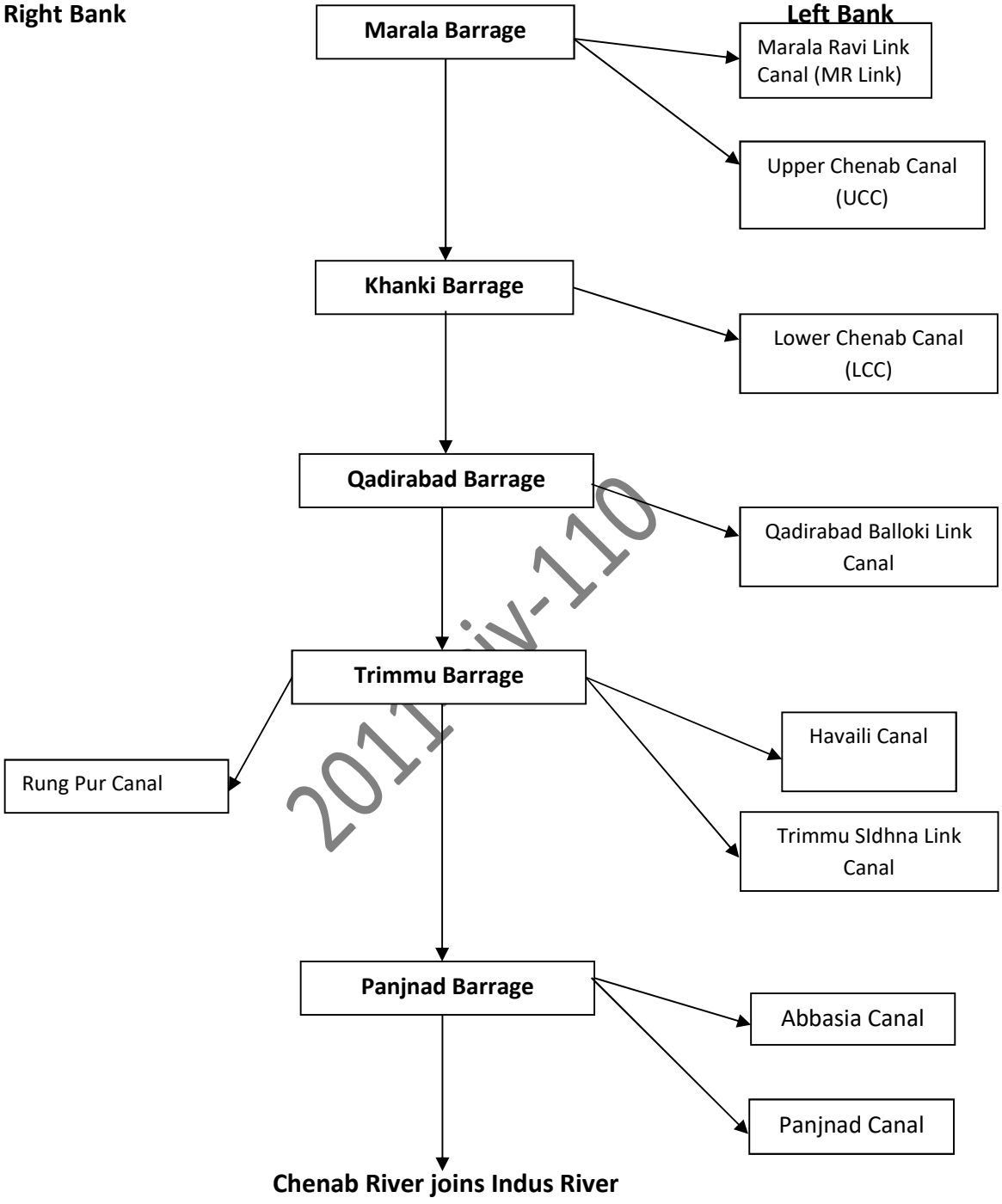
i. Rasool Qadirabad Link Canal:

Length	31 miles
Width	330 ft
Depth	14ft
Authorized full supply	19000 Cusecs

ii. Lower Jehlum Canal:

Length	398 miles
Width	175 ft
Depth	9 ft
Authorized full supply	5280 Cusecs
Full supply level	709 (SPD)
Crest of head regulator	703 (SPD)
Gross commanded area	16, 22,100 acres
Cultural commanded area	14, 99,674 acres

Structures on Chenab River:



1. Marala Barrage:

Location.	Chenab
Max. Design discharge.	11, 00,000 cusecs
Recorded discharge	11, 00,000 cusecs
Total width between abutments.	4472.33 ft.
No. of bays.	66
Width of each bay.	60 ft.
Year of construction	1967
Maximum flood level on U/S	816 (SPD)
Maximum flood level on D/S	------
Pond level	812

Canals Off taking from Marala Barrage:

i. MR link Canal:

Length	63 miles
Width	345 ft
Depth	14.6 ft
Authorized full supply	22000 Cusecs
Full supply level	-----
Crest of head regulator	-----

ii. Upper Chenab Canal (UCC):

Length	83 miles
Width	300 ft
Depth	13 ft
Authorized full supply	16500 Cusecs
Full supply level	803 ft
Crest of head regulator	795 ft
Gross commanded area	15, 33,800 acre
Cultural commanded area	14, 44,992 acres

2. Khanki Headwork:

Location.	Chenab
Max. Design discharge.	10, 50, 000 cusecs
Recorded discharge	10, 86,000 cusecs
Total width between abutments.	4600 ft.
No. of bays.	6
Width of each bay.	515.25 ft
Year of construction	1891
Maximum flood level on U/S	739 (SPD)
Maximum flood level on D/S	736 (SPD)
Pond level	733 (SPD)

Canals off taking from Khanki Headwork:

i. Lower Chenab Canal (LCC):

Length	40 miles
Width	250 ft
Depth	11 ft
Authorized full supply	11500 Cusecs
Full supply level	725 ft
Crest of head regulator	726 ft
Gross commanded area	37, 00,200 acres
Cultural commanded area	29, 97,435 acres

3. Qadirabad Barrage:

Location.	Chenab
Max. Design discharge.	9, 00, 000 cusecs
Recorded discharge	9, 48, 000 cusecs
Total width between abutments.	3,373 ft.
No. of bays.	50
Width of each bay.	60 ft.
Year of construction	1967
Maximum flood level on U/S	704 (SPD)
Maximum flood level on D/S	700 (SPD)
Pond level	701 (SPD)

Canals off taking from Qadirabad Barrage:

i. Qadirabad Balloki Link Canal:

Length	102 miles
Width	335 ft
Depth	13 ft
Authorized full supply	18600 Cusecs
Full supply level	699 ft
Crest of head regulator	-----

4. Trimmu Barrage:

Location.	Chenab
Max. Design discharge.	6, 50,000 cusecs
Recorded discharge	9, 40,000 cusecs
Total width between abutments.	3,209 ft.
No. of bays.	42
Width of each bay.	60 ft.
Year of construction	1939
Maximum flood level on U/S	492 (SPD)
Maximum flood level on D/S	490 (SPD)
Pond level	490 (SPD)

Canals off taking from Trimmu Barrage:

i. Rungpur Canal:

Length	86 miles
Width	122 ft
Depth	7 ft
Authorized full supply	2700 Cusecs
Full supply level	489ft
Crest of head regulator	------
Gross commanded area	3, 57,800 acres
Cultural commanded area	3, 45,570 acres

ii. Trimmu Sidhnai Link Canal (TS Link):

Length	50 miles
Width	240 ft
Depth	12 ft
Authorized full supply	11000 Cusecs
Full supply level	491 ft
Crest of head regulator	481 ft

iii. Havaili Canal:

Length	-----
Width	1758 ft
Depth	12 ft
Authorized full supply	5200 Cusecs
Full supply level	489 ft
Crest of head regulator	431 ft
Gross commanded area	11, 23,200 acres
Cultural commanded area	10, 11,064 acres

5. Panjnad Barrage:

Location.	Chenab
Max. Design discharge.	7, 00, 000 cusecs
Recorded discharge	8, 02, 516 cusecs
Total width between abutments.	3,400 ft.
No. of bays.	47
Width of each bay.	60 ft.
Year of construction	1932
Maximum flood level on U/S	340 (SPD)
Maximum flood level on D/S	340 (SPD)
Pond level	338 (SPD)

Canal off taking from Panjnad Barrage:

i. Panjnad Canal:

Length	57 miles
Width	240 ft
Depth	12 ft
Authorized full supply	9000 Cusecs
Full supply level	336 ft
Crest of head regulator	333 ft
Gross commanded area	15, 09,400 acres
Cultural commanded area	13, 45,697 acres

ii. Abbasia Canal:

Length	47 miles
Width	55 ft
Depth	6 ft
Authorized full supply	1100 Cusecs
Full supply level	335 ft
Crest of head regulator	330 ft
Gross commanded area	1, 30,700 acres
Cultural commanded area	1, 13,339 acres

Refrences:

http://www.pakirsa.gov.pk/wateraccord.html

http://wapda.gov.pk/htmls/pgeneration-dam-tarbela.html

http://www.wapda.gov.pk/htmls/ghazibarotha.html

http://www.wapda.gov.pk/htmls/cjlinkcanal.htm

http://www.wapda.gov.pk/htmls/chashrightcanal082011.htm

http://www.wapda.gov.pk/htmls/water-dams-mangla.html