PAKISTAN

1. PHYSIOGRAPHY

Pakistan is located in the north-west part of the Indo-Pakistan sub continent about in the middle of the South Asian 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 24° and 37° North and longitudes 61° and 75° East. Total area is 310,400 square mile (803,936 Km^2) of which one per cent comprises water areas. It is a land of varied landscapes ranging from perpetually snow capped 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 120° F (49° C). Physiographically the country can be divided into three regions :

- Mountainous north and north-west 241,647 Km^2;
- Table lands of Balochistan 242,683 Km^2 and
- Vast alluvial plain of the Indus River and tributaries 319,605 Km^2.

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 1.

Table 1. Agricultural land capability

{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 38°C and 40°C from May to July over greater part of the Indus Plain. Temperatures of the order of 49°C are not rare. The highest maximum temperature of 53°C 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 20°C during December and January and minimum temperatures generally between 2.2°C to 5°C (36°F to 41°F) but occasionally approaching freezing point. The lowest minimum temperature of -26°C 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 give in Table 2

TABLE 2

{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

Source : Climatic Normals of Pakistan (1961-90)
Pakistan Meteorological Department Karachi

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 t he 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.

Table 3. Farm distribution by size in Pakistan

{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

Source : Agricultural Statistics of Pakistan 1997-98.

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.

A series of SCARPs (Salinity Control and Reclamation Project) were started in 1959 to deal with salinity and waterlogging problem in the country and results have been encouraging in salinity control. The position in 1977-79 compared to the 1960 is given in Table 4.

TABLE 4

{PRIVATE }Salinity Surface Salinity	1960 (%)	1977-79 (%)
Salt free	53	72
Slight Saline	18	11
Moderate Saline	11	6
Strong Saline	16	8
Others	2	3
Profile Salinity		
Not affected	48	61
Saline	4	11
Sodic	24	3
Saline Sodic	23	24
Others	1	1

The figures in Table 4 show distinct improvement in reduction of salinity and sodicity.

6. WATER RESOURCES

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 m^3) with about 30,800 million m^2 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 m.

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, the

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.

During the 75 year period from 192-23 to 1997-98 the figures of yearly river water supplies are given in Table 5.

Table 5. Water flow supplies

(In million m^3)

{PRIVATE }River	Highest Flow	Mean Flow	Lowest Flow
Indus	148,000 (1959-60)	111500	77900 (1974-75)
Jhelum	40,400 (1957-58)	28700	16700 (1971-72)
Chenab	43,000 (1950-51)	32000	22500 (1974-75)

These figures are for the rim stations of Kalabagh on the Indus, Mangla on the Jhelum and Marala on the Chenab river.

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 m^3 of sediment enters the Indus basin and about 185 million m^3 passes out to the delta. This leaves a balance of 245 million m^3 in the reservoirs, rivers and irrigation channels annually.

SURFACE WATER DEVELOPMENT

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. An 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) escaped 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.

GROUND WATER DEVELOPMENT

Under the programme of the control of waterlogging and salinity in the irrigated areas of Pakistan, the first large scale project was launched in Central Rechna Doab in 1959 under the designation 'Salinity control and Reclamation Project (SCARP-I). The construction of 2,069 tubewells in this project was completed in 1962. As the result of the operation of these tubewells the waterlogging to the project area has been completely eliminated and a major part of the salinity effected land has been reclaimed. As the result of the additional irrigation supplies available from pumping of tubewells the cropping intensity in the areas has increased to over 100 per cent as compared to the pre-project intensity of 78 per cent.

In addition to SCARP-I, WAPDA had installed more than 17 thousands fresh and saline groundwater tubewells through construction of 56 SCARP Projects by June 1998. These SCARPS also include 11 thousand Kilometers of surface drains and 9,500 Kilometers of sub-surface drains covering an area of 6.5 million hectares. Summary of the SCARP completed is presented as Table 6.

Table 6. Completed scarp

{PRIVATE }Sr. No.	Project	Gross Area (M.Ha)	Tubewell (No.)	Surface Drain (Km)	Tile Drain (Km)
Upper Indus Plains					
1.	SCARP I	0.493	2069	-	-
2.	SCARP II	0.992	3284	682	-
3.	SCARP III	0.518	1696	240	-
4.	SCARP IV & Drainage IV	0.278	935	615	800
5.	SCARP V	0.266	260	248	-
6.	SCARP VI	0.678	1137	458	-
7.	SCARP VII	0.408	101	194	-
8.	SCARP VIII	0.076	256	177	-
9.	Hadali	0.066	71	128	-
10.	Paharang Drain	0.029	-	84	-
11.	D.G. Khan (Saline)	0.135	-	98	-
12.	Antiwaterlogging Project along link canals	0.075	241	73	-
13.	Tubewell Replacement	-	1472	-	-
14.	Peshawar	0.055	218	267	4
15.	Bannu	0.036	176	27	-
16.	Chashma Command Area Development	0.063	-	92	1500
17.	Mardan	0.089	-	320	4277
Lower Indus Plains					
1.	Khairpur	0.178	540	550	-
2.	N. Rohri	0.321	1192	-	-
3.	Larkana Shikarpur	0.284	-	1212	-
4.	Ghotki	0.178	1080	-	-
5.	S. Rohri	0.219	1214	-	-
6.	LBOD Spinal Drain	-	-	968	-
7.	Kotri Stage I&II	0.734	-	3508	-
8.	N. Dadu	0.209	-	709	-
9.	East Khairpur	0.018	-	-	976
10.	Larkana Shikarpur Remodelling	-	-	240	-
11.	Tubewell Replacement	-	233	-	-
12.	Hairdin I&II	0.072	-	322	-

Source : Monthly Progress Report Water Wing

7. BRIEF HISTORY OF IRRIGATION AND DRAINAGE

IRRIGATION

Early Development

There is evidence that irrigation has been practiced along the Indus system of rivers from 3000 B.C. In the beginning, only the narrow strips of land along the river banks were irrigated, but with time, irrigation was extended to other nearby areas by breaching the banks or the natural levies of the rivers to bring water to the low lying fields. This was done only during high water periods.

The first canals were constructed some five or six centuries ago and extended under the Mughal Emperors. The early canals were inundation channels and delivered water to the fields when rivers were in high flow during the summer. They tended to be unpredictable in operation and subjected both to frequent breaches and serious siltation problems. The next stage in the evaluation of the Irrigation System was construction of perennial canals having permanent headworks. These headworks either did not extend across the entire stream or allowed the floods to pass over their crests. The first evidence of perennial irrigation on any of the Indus rivers dates back to early seventeenth century when a 80 Km long canal was constructed by the Mughal Emperor Jahangir (reigned 1605-27) to bring water from the right bank of the Ravi to the pleasure gardens of Sheikhpura near Lahore.

The irrigation system which exists today was stated in the nineteenth century under the British administration. In the early 19th century, there were numerous inundation canals leading from the Indus River and its tributaries. The more important of these were the Upper and Lower Sutlej canals, the Shahpur canals, the Chenab canals and the Indus canals in Punjab and Bahawalpur. In the Sindh, where the Indus River flows more or less on a ridge, conditions were particularly favorable for inundation canals. Among Sindh's 19th century canals were the Desert, the Begari, the Sukkur, the Fuleli, the Pinyari and the Kalri canals.

From the middle of the 19th century onwards, a large number of inundation canals were remodelled and fitted with permanent headworks and new canals with weir controlled supply were constructed for the Sindh, Punjab and NWFP areas.

The first permanent headworks constructed in 1887 was the Marala Barrage, which started supplying water to the Upper Chenab Canal in 1915. In 1889, a project was prepared for the irrigation of part of the Rechna Doab. The project envisaged the diversion of the Chenab waters by means of a weir at Khanki. The project was sanctioned in 1890 and the Chenab Canal, now called the Lower Chenab Canal, was opened in 1892.

A similar scheme was sanctioned for the irrigation of the area between the Chenab and the Jhelum (Chaj Doab) from a weir at Rasul on the Jhelum River. Construction was started in 1897 and the Jhelum Canal, now called the Lower Jhelum Canal was opened in 1901.

The Triple Canal Project was sanctioned in 1905 and became the first project to transfer water from one river to another. The Triple Canal Project involved the diversion of the available waters in the Jhelum River across the Chaj and Rechna Doabs. The project consisted of a feeder canal from the Jhelum River at Mangla to the Chenab River above Khanki (Upper Jhelum Canal), a feeder canal from Marala on the Chenab River to the Ravi River above Balloki (Upper Chenab Canal) and construction of a barrage (level crossing) on the Ravi River at Balloki to divert the transferred water into the new Lower Bari Doab Canal (LBDC). The Triple Canal Project Chenab

Canals are primarily feeder or link canals but they also provide considerable irrigation enroute in the Upper parts of the Chaj and Rechna Doab.

After World War-I, the Sukkur Barrage Project, the first barrage constructed ont he Indus River was started in 1923 and was commissioned to irrigation in 1932. During 1921 the Sutlej Valley Project was sanctioned for the development of the Punjab, Bikaner (now in India) and Bahawalpur states areas. The Project consisting of four (4) weirs ont he Sutlej River at Ferozepur, Sulemanki, Islam and Panjnad and 11 canals were completed by 1933.

The Trimmu Barrage, located below the junction of the Jhelum and the Chenab Rivers was started in 1837 and completed in 1939, was the last barrage completed prior to World War II. At the time of independence the Kalabagh Barrage (Jinnah), Kotri Barrage on the Indus River and the Bhakra Dam in India on the Sutlej River were under construction.

Post Independence - Pre - Water Treaty (1947-60)

Partition of the Punjab Province left the Bhakra Dam, the headworks of the old Upper Bari Doab Canal at Madhopur and those at Ferozepur on the Sutlej in India. Pending final settlement of the Indus Water Dispute, it became urgent for Pakistan to secure a supply of water for the Upper bari Doab and the Sutlej Valley. Thus the 164 Km Bombanwala-Ravi-Bedian Dipalpur Link and Balloki-Suleimanki Link I were constructed between 1951 and 1954 and the 101 Km Marala-Ravi Link was built between 1954 and 1965, all to bring additional water from the Chenab River to the east.

The Pakistan Government continued the work which had been planned by the British Administration and completed the kalabagh Barrage in 1947, the Kotri Barrage in 1955 and the Guddu barrage in 1963.

After independence, the Lower Sindh Inundation Canals were converted into weir-controlled canals to command culturable area of 809,400 ha (2 million acres) and to serve a local culturable commanded area of 1.13 million ha (2.8 million acres) of land, with the construction of the Kotri Barrage at Kotri (1947-1955). Similarly, the Guddu Barrage built (1953-1962) at the head of Upper Sindh Inundation Canals system, converted the Upper Sindh Inundation Canals into a controlled perennial canals system for the irrigation of 1.13 million ha of land.

The Taunsa Barrage built (1953-1958) on the Indus provided weir-controlled irrigation supplies to culturable commanded area of 687,970 ha. This barrage is multipurpose and also provides bridges for road and railway and head regulator for the Taunsa-Panjnad Link-Canals.

In 1954, the World Bank put forward a proposal for the equitable distribution of the water resources available to India and Pakistan. The proposal has three essential features:

i. The waters of the three western rivers - the Indus, the Jhelum and the Chenab - were to be allocated to Pakistan, and the waters of the three eastern rivers, the Ravi, the Beas and the Sutlej - to India. Requirements of the areas within Pakistan, hitherto fed by the eastern rivers, would in future be met by waters to be transferred from the western rivers by means of a system of replacement works. It was estimated that some 17,300 million m^3 (14 million acre feet) would be required, ultimately, to replace the water designated for use in India.

ii. India would make a contribution to the cost of the replacement works.

iii. During the construction phase, India would limit her withdrawals from the eastern rivers in proportions to match Pakistan's capacity to replace.

It took eight years of negotiations before an agreement was reached and a Treaty signed on 19 September 1960. To compensate Pakistan for the loss of the water of the eastern rivers, six friendly countries and the World Bank together with Pakistan and India agreed to provide funds to enable a system of replacement works to be constructed which would transfer water from the western rivers to the areas that were dependent on supplies from the eastern rivers.

Indus Basin Projects (Replacement Works)

The engineering plan of the Indus Basin Project redefined by the 1964 (Supplemental) Agreement, consisted of the following major works :

- An earthfill dam on the Jhelum River (Mangla Dam) with a live storage capacity of 6.59 million m^3, and hydro-electric power equipment with an installed capacity of 300,000 KW.
- A series of new major inter-river link canals joining the Indus to the Jhelum, the Jhelum to the Chenab, the Chenab to the Ravi and the Ravi to the Sutlej. The net volume of water to be transferred form the three western rivers (excluding conveyance losses) would be 17,280 million m^3 (14 million acre-feet) annually.
- Five new barrages and an inverted syphon at Mailsi.
- Remodelling of the two existing barrages, three existing inter-river link canals and existing canals affected by the construction of new links.
- The organization and administration by the World Bank of a study of the water and power resources of Pakistan (the Indus Special Study intended to provide the Government of Pakistan with a basis for development planning int he water and power sectors. The first objective of the study was the completion of report covering the technical feasibility, the construction cost and the economic return of a dam on the Indus at Tarbela.

The link canals would convey waters from the western rivers and the water to be stored at Mangla and Tarbela to the lands of the eastern rivers which historically have been dependent on waters allocated to India under the Treaty. There are three systems of link canals. Two of the systems, the Rasul-Qadirabad-Balloki-Suleimanki System (R.Q.B.S.) and the Trimmu-Sidhnai-Mailsi-Bahawal System (T.S.M.B) connect the Jhelum River through to the Sutlej and the third system Chashma-Jhelum System (C.J) connect the Indus with the Jhelum.

The five barrages and one syphon-cum-barrage as given in Table VIII were included in the Indus Basin Project.

The five barrages and Mailsi Syphon have a total length of nearly 5.6 Km and an aggregate discharge capacity of 125,000 m^3/s with the new and existing canals off-taking from these barrages having an aggregate capacity of 3.398 m^3/s.

In addition to the new works, the Indus Basin Project embodied the remodelling and rehabilitation of a number of old structures and canals. The Balloki Barrage was remodelled for passing the highest recorded flood of 1955 and for handling the increased withdrawals by the Balloki-Suleimanki links.

Table 7.

{PRIVATE }Sr. No.	**Source**	**River**
i.	Mailsi Syphon-cum-barrage	Sutlej
ii.	Sidhnai Barrage	Ravi
iii.	marala Barrage	Chenab
iv.	Chashma Barrage	Indus
v.	Qadirabad Barrage	Chenab
vi.	Rasul Barrage	Jhelum

The Marala-Ravi, BRBD and Balloki-Sulemanki link canals were also remodelled to increase capacities and provide additional flood protection. Numerous canals and their structures were remodelled throughout the Punjab to distribute the reallocated water supplies.

The total irrigated area is covered essentially by 43 principal canal systems of which 23 are in Punjab, 15 in Sindh and 5 are in NWFP. Seventeen canals have a head capacity of 198 m^3/s to 425 m^3/s. These canals command a gross area of 15.80 million ha. In addition there are eight major link canals ranging in capacity from 184 m^3/s to 614.5 m^3/s. The total CCA is 14.17 million ha. About 3.66 million ha of the total CCA are at present designated for non-perennial supplies usually from mid-April to mid-October. Non-perennial areas do, however, receive occasional rabi water and in some years fairly consistent deliveries reach the farmers, when river flows are surplus to the requirements of the perennial canals.

DRAINAGE

In Pakistan the potential need for drainage, particularly subsurface drainage, was realised from the time large-scale diversion works were constructed for irrigation. Consequently a network of observation points were established to keep a watch on the rise of the water table. As was expected, the water table, in the absence of any natural subsurface drainage started to rise at the rate of 0.3 to 0.46 m per year. Depending upon the initial depth of the water table, areas started getting waterlogged, first along the main canals and then over larger contiguous areas.

The drainage measures were first confined to the local affected areas, but as the threat of waterlogging became more widespread, broader measures were advised.

Surface drainage, to protect the agricultural lands from the effects of excess storm water runoff and flooding, had not been considered to be a very critical requirement, although damages occurred from these causes rather infrequently in most areas. In the southern portion of the Indus Plains however, storm water drainage is needed due to the frequent occurrence of intensive widespread storms. Flooding during high river stages is not too frequent in the Upper Indus Plain, but in the Lower Indus Plain where the Indus, flows along the ridge, flooding has been a serious problem. Here flood protection bunds have been constructed in a reach of 483 Km to confine the Indus floods.

The drainage measures which were implemented in Pakistan in the early stages were mostly intended to correct local problems or attempted to reduce ground water recharge.

Starting with unsuccessful attempts at canal lining different approaches were tried from 1926 to 1933. Those consisted of the provisions of seepage drains along the main canals, lowering of full supply level by climinating canal falls and restriction of canal supplies. A number of measures were taken up from 1933 to 1941, when a large network of surface drains was constructed in the irrigated areas of the northern Indus Plains. These surface drains were intended to remove the storm water runoff quickly so as to cut down on what was considered to be the major source of ground-water recharge.

There after new approach was tried, which consisted of installing tubewells close to the canals and putting the pumped water back into the canals, the Objective being to create an unsaturated zone below the canals in order to reduce the seepage.

An effective approach to the solution of drainage problems of Pakistan was initiated in 1954 when a comprehensive programme of hydrologic, ground water and soils investigation was started in the Upper Indus Plains. At that time an aerial reconnaissance survey indicated that more than 4.45 million ha were poorly drained or waterlogged and some 6.47 million ha were affected by salinity to some degree of which 2.02 million ha were severely salinized.

These investigations, which were later extended to the Lower Indus Plains, furnished a scientific basis for implementing drainage measures, which were embodied in what were termed as Salinity Control and Reclamation Projects or 'SCARP's for short. The first SCARP covering an area of 485,620 ha was started in 1959 and completed three years later. It was the forerunner of similar large-scale projects in which drainage was to be achieved by pumping out ground water and the pumped water was to be utilized for supplementing canal supplies for a more intensive irrigated agriculture. In these projects, the ground-water pumping was planned at a rate sufficient to dominate the recharge so that the water table could be progressively lowered. A preliminary appraisal of the drainage requirements for the irrigated areas of Pakistan as a whole was carried out in 1961 , and this indicated that vertical drainage by means of tubewells could be achieved more effectively in the greater portion of the area and that tile drainage may have to be used in the remaining area except that which was devoted to rice culture and where surface drainage was required. The estimates indicated that 31,500 tubewells of 85 to 113 1/s capacity would be needed (28,000 for irrigation and drainage and 3,500 for drainage alone) besides 12,070 Km (7,500 miles) of disposal channels and 40,234 Km of drains.

A team of experts from U.S.A. made a detailed study of the problem of waterlogging and salinity in the Indus Plains. The main recommendations made by this team of experts was to make a coordinated attack on all aspects of the agricultural problems in the region, such as additional irrigation waters, more fertilizers, improved seed and crop varieties, pest control, better cultivation and salt free soils. The team suggested that efforts should be concentrated on project areas of manageable size by shifting the emphasis from one based on function to that based on area. Since then more intensive investigations and studies have been carried out and the drainage works have been defined in greater detail for the different canal commands.

8. IRRIGATION AND DRAINAGE METHODS USED

Irrigation Methods:

Culturable land that can be irrigated for at least one full cropping season is the foundation of Pakistan's agriculture. The 14.41 million ha culturable commanded area (CCA) under canal irrigation in the Indus Plains contribute about 80 per cent of the Nation's total agricultural production, with the balance of some 8 million ha watered by rain, residual flood moisture, isolated irrigation systems and ground water. The remaining 59 million ha are made up of forests, range lands, deserts, mountains and open water.

Although lands outside the canal commanded area produce only about one-fifth of the total agricultural output, they support some 11 to 12 million of the Nation's poorest people, many of whom are nomadic. Even though the potential contribution of these lands in the future will probably be even smaller in the future, improvements in agriculture in these areas has great importance in achieving regional economic equity, social justice and stability.

Table 8. Irrigation methods and their extent

{PRIVATE }Sr. No.	Type of Irrigation	Area (Million ha)	Percentage
1.	Canal Irrigation		
	Perennial	8.19	10.3
	Non-perennial	5.80	7.3
	Culturable waste inside CCA	- 2.02	- 2.6
	Sub-Total	11.97	15.0
2.	Wells, streams, karezes, etc	2.22	2.8
3.	Sailaba (riverain)	1.25	1.6
4.	Sailaba (torrent)	0.97	1.2
5.	Barani (rainfed)	3.68	4.6
	Sub-Total	8.12	10.2
6.	Total cultivated area	20.09	25.2
7.	Other land uses		
	i. Range lands	8.62	10.8
	ii. Forest	2.83	3.6
8.	Total suitable for agriculture & forestry.	31.54	39.6
9.	Total unsuitable for agriculture and forestry	48.12	60.4
10.	Total area of Pakistan	79.60	100.0

Source : RAP, 1979.

Rainfall is almost universally insufficient to meet full crop water needs and 14.41 million ha are commanded by irrigation canal systems. Most of the irrigation water is supplied from rivers by canals; however, an increasing portion of the water supply, about 40 percent at the watercourse, is obtained from ground water by tubewells. The total potential irrigation supply is about 148,017 million m^3 at the canal heads, with about 133,218 million m^3 currently being diverted. After canal losses, about 101,240 million m^3 are being delivered to the watercourses, supplemented by about 49,340 million m^3 from ground water. Delivery losses between watercourse head and the field vary considerably but average about 40 per cent . The reduction of delivery losses and the improvement of water management towards meeting the actual crop needs present a great opportunity and challenge for increased irrigation.

The perennial canals supply water for both the Rabi and Kharif crops while the non-perennial canals are only run during Kharif (or the flood) season. Several non-perennial areas have now been converted to perennial cultivation with the help of tubewell water or storage supplies made available during the dry season.

Drainage Methods

There are tow types of drainage problems in irrigated areas of Pakistan:

1. Problems arising from a high water table for unusable groundwater areas. This creates a need for pure drainage with accompanying effluent disposal system, for usable groundwater areas the aquifer may be used as a source of water supply in the process of draining the area: and

2. Problems due to surface flooding caused by severe rain storms. This requires surface drainage systems. So far, policies and actions have been primarily directed at "drainage-cum-water supply" in usable ground water areas. There have been considerable projects implemented catering purely drainage of unusable ground water. The same is true to a certain extent for surface drainage projects and programmes.

The Indus Special Study (ISS) provided for the construction of two major surface drainage projects, the Sukh-Beas Drainage Scheme and the left bank Outfall Drain (LBOD). Project planning report was prepared by WAPDA in 1969. First phase of LBOD spinal drain (968 Km) was started in 1973 and was commissioned in 1986. The remaining LBOD component project consists of 2175 saline water tubewells, 1814 Km long surface drains and 2817 Km of Tile + Interceptor Drains. The commutation physical progress till 1998 is 94%.

A feasibility report of Sukh Beas Drainage project was prepared in 1978. the project is subdivided into parts named Centre Bari Doab Canal (CBDC), Pandoki Unit, Sukh Beas below BS Link Sukh Nai Outfall channel and CBDC remaining. The first two parts have been completed since 1997.

By June 1998, twelve SCARPS covering an area of 2.6 million hectors, are in progress. Under these schemes 2448 numbers saline groundwater tubewells, 3152 kilometers of surface drains and 2870 kilometers of Tile Drains are to be provided to eradicate waterlogging and salinity out of these, of 8 drainage projects are in Punjab (3 of these are tubewell drainage projects and 5 are surface drainage projects), 3 surface drainage projects in Sindhh and one Tile Drainage Project in NWFP. List of these projects is presented under Table -IX.

All above mentioned schemes/projects are planned on project boundary basis and this approach could not touch the problem at a wider scale. Thus a country wide programme called National Drainage Programme (NDP) is initiated in 1997. The programme covers entire canal irrigated areas of the Indus Basin and Baluchistan and NWFP.

NDP's major scope of work is as under :

-New drainage schemes.	2,22,582 ha
- Remodelling/Extension of Existing surface drains.	4100 Km
- Construction of Interceptor Drains.	400 Km
- Constructing Sub Surface Drains.	21853 ha
- Rehabilitation/Replacement of Saline Tubewells.	863 Nos.

Table 9. On-going drainage projects

{PRIVATE}Sr. No.	SCARPS	G.A (Mha)	Tubewell (No.)	Surface Drains (Km)	Tile Drains (ha)
PUNJAB					
Tubewell Drainage Project					
1.	Gogera Khewra Phase-II	0.177	58	197	Nil
2.	Shorkot Kamalia Saline	0.023	215	78	Nil
3.	2nd SCARP Transition	Nil	Transferring from public to private sector		
Surface Drainage Project					
4.	Upper Rechna (Deg Unit)	0.189	Nil	330	Nil
5.	Fordwah Sadiqia Phase-I (Remaining)	0.250	Nil	402	Nil
6.	Fordwah Sadiqia (South) Phase-I	0.121	Nil	159	1416
7.	D. G. Khan Integrated	0.142	Yet to be decided		
8.	Panjnad Abbasia Phase-II	Nil	Canal Remodelling and works in pond area.		
SINDH					
Surface Drainage Project					
1.	LBOD Stage-I	0.577	2175	1814	22260
2.	Kotri Part-II Stage-III	0.567	Nil	Not available	
3.	Lower Indus Right Bank Stage-I	0.399	Nil	172	Nil
NWFP					
Tile Drainage Project					
1.	Swabi	0.156	Nil	530	28330

Source : Monthly Progress Report Water Wing (May, 1999).

The drainage and reclamation programme is being assigned top priority as it aims at checking/mitigating the severs problem of waterlogging and salinity, especially in the areas where water table lies within 0-150 cm (0-5 ft) to the surface. The activities include construction of open and interceptor drains, installation of drainage tubewells, and laying tile drainage system.

To take up the drainage works on more scientific lines, to establish a comprehensive and environmentally feasible drainage network, and to give impetus to financially starving projects, the National Drainage Programme (NDP) has been given pivotal role in country's drainage schemes and will be largely completed under Ninth Five Year Plan (1998-2003).

It is expected that 1.21 million hectares of affected lands will be reclaimed from the ever challenging menace of waterlogging and salinity during the Ninth Five Year Plan by installing 1150 saline groundwater tubewells and transitioning 5000 public tubewells, constructing and rehabilitating 3300 kilometer open drains and laying tile drainage system in an area of 200,000 hectares.

9. STATISTICS RELATING TO IRRIGATION AND DRAINAGE

Area cultivated (net) in 1947-1948	14,690,000 ha
Area cultivated (net) in 1958-1959	16,550,000 ha
Area cultivated (net) in 1966-1967	19,690,000 ha
Area cultivated (net) in 1997-1998	22,000,000 ha

{PRIVATE }Area irrigated by sources (ha)	**1947-48**	**1996-97**
Government canals	7,787,520	7,310,000
Private canals	197,400	480,000
Tanks	16,200	-
Wells	972,060	160,000
Tubewells	Nil	3,000,000
Other sources	464,600	180,000
Canals + Tubewells	-	6,740,000
Total	9,437,870	17,870,000