A FEW SUGGESTIONS TO CONSERVE FLOOD RUN-OFF AND TO RECOVER FRESH WATER FROM THE SALINE WATER ZONES OF THE INDUS PLAINS

By
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SYNOPSIS

This paper discusses ways and means to augment the present use of water resources of West Pakistan. It is put forth that the flow in the rivers, during the three monsoon summer months, constitutes about 58 per cent of the total. It is much more than the present diversion capacity of the canals so that the excess water runs off into the sea.

During the months of July and August, the rainfall intensity is also about 50 per cent of the total annual precipitation. This factor further augments the run-off in the rivers. Even the canals are closed during high floods and the farmers of certain areas have no demand of water. All these factors cause a run-off of nearly 40 maf. of water into the sea. At present there are no immediate plans to conserve a part of this huge wastage. Any surface storage, planned to be constructed, will not only take several years to complete but also will be very costly.

Ground water is the next source of water. It has accumulated in the formation during several centuries. It is constantly being augmented by infiltration from the rivers, rainfall, canals, water courses, agricultural fields etc. The present estimates are that about 50 maf. of water, 33 maf. in the northern regions of the Punjab and Bahawalpur and about 17 maf. in the Sind area is infiltring underground. This recharge is occurring on the irrigated lands, both containing good qulity and saline quality of ground water. Although during the last two decades, measures have been taken to recover a part of the recharge from the fresh ground water zones but at present there are no proposals for utilization of the recharge occurring on areas possessing saline ground water. Such zones in the Punjab and Bahawalpur constitute about 25 per cent of the total and nearly 80 per cent in Sind. The amount of recharge into the area overlying saline ground water is about 14 maf. for Sind and about 8 to 9 maf. for the Punjab and Bahawalpur. In this paper, suggestions are put forth to recover quite a large proportion of this 22 maf. of fresh water, draining into the area possessing saline ground water. The methods suggested include the installation of compound tubewells—a compound tubewell possessing multiple strainers, or a tubewell with multiple strainers.

As to the conservation of a portion of the 40 maf. of annual summer run-off, it is suggested that in the Indus plains there are many sites with potential recharge sources. If those sites are pumped intensively to dewater a certain depth of the formation during the winter months, it will be possible to recharge the formation during the summer high flow periods. An area of 700 sq. miles dewatered to a depth of 10 feet can hold about one maf. of water.

There are some areas in the Indus plains which still have deep ground water. Thus possibilities of holding the recharge in the unsaturated formations exist. Suggestions for a few sites are put forth, while others can be searched out where surface water during the summer flood months can be retained and conserved.

Basic Information

West Pakistan constitutes an area of 198.7 m. acres (310400 sq. miles). It has two main hydrological divisions, those of the Indus River system and that of Baluchistan.

Baluchistan covers an area of about 80.64 m. acres. A part of this area lies within the hydrological division of the Indus, which constitute 139 m. acres. An area of Baluchistan outside the Indus Basin constituting 61 m. acres, is made up of Kharan Desert and Makran Coast. The Indus plains which start below the salt range constitute nearly 50 m. acres of flat lands. Thirty-two million acres of these have irrigation facilities.

Above the Salt Range lies the Potwar Plateau which has limited irrigation facilities due to the nature of its terrain. Next to it lies the valleys of Peshawar, Mardan, Bannu, etc. These are located on the west side of the Indus. According to the Colombo Plan aerial surveys,[2] the extent of lands in use in the three areas of the Indus Basin *i.e.* Peshawar, the Punjab and Sind is given in Table 1.

TABLE No. 1—*Land-use division of Indus Basin*, 1000 *Acres*

Division	Irrigated	Barani	Sub-Total	Unknown	Unusable	Total of each Division
Peshawar	2,788	1,299	4,087	924	2,478	7,489
Punjab	19,963	6,330	26,291	10,494	6,060	42,911
Sind	9,217	—	9,217	5,076	6,314	20,617
Total	31,968	7,269	39,595	16,494	14,852	71,017

Out of 71.0 m. acres of the Indus Basin, about 40 m. acres are cultivated, 32 m. acres by canal irrigation and the rest 7.6 m. acres depend upon natural precipitation. Nearly half of the barani cultivated land lies in Potwar plateau (2.7 m. acres) and in Salt Range piedmont (0.75 m. acres).

In this paper we will be dealing with only those areas which lie below the salt Range, and are called the Indus Plains.

Water Resources

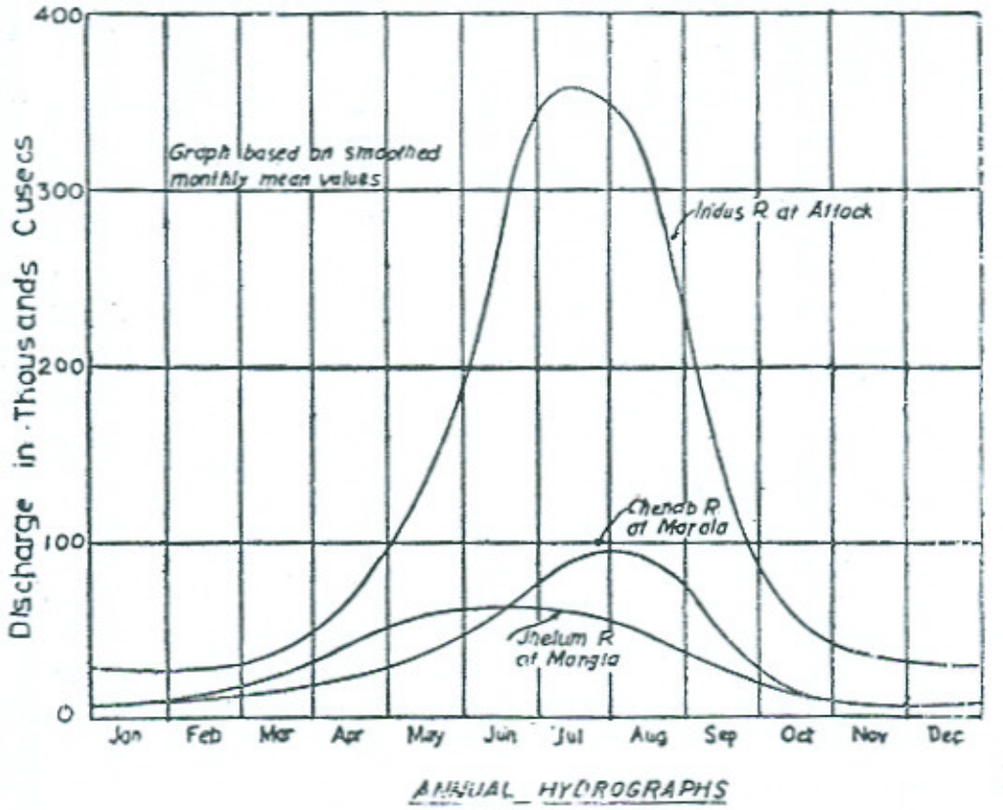
There are three main sources of water which are utilized for irrigation of the land of the Indus Basin and in particular the Indus Plains. These are :

(*i*) Surface flows of the rivers,

(*ii*) Rainfall, and

(*iii*) Ground-water.

Presently, the resources of only three rivers, the Indus, Jhelum and Chenab, are available in the country. These are perennial rivers drawing their supplies from the perpetual glaciers, snow and from the rainfall run-off. Typical hydrographs of the three rivers are shown in Fig. 1. The summer supplies particularly during the months of June, July and August are the highest. In Table 2, is given some idea of the monthly[3] flows of the three rivers.



ANNUAL HYDROGRAPHS

Fig. 1

TABLE No. 2—*Mean Monthly Flows of three Rivers, the Indus, Jhelum and Chenab. Values in maf. corrected after future withdrawal by India*

Months	Indus at Attock	Jhelum at Mangla	Chenab at Marala	Total
Jan.	1.70	0.52	0.50	2.73
Feb.	1.61	0.72	0.63	2.97
Mar.	2.45	1.55	1.02	5.03
Apr.	4.28	2.56	1.28	8.13
May	8.33	3.61	2.12	14.07
Jun	15.62	3.66	3.42	22.71
Jul.	22.53	3.59	5.47	31.60
Aug.	19.79	2.81	5.40	28.01
Sep.	8.69	1.60	2.87	13.15
Oct.	3.56	0.83	0.97	5.37
Nov.	2.12	0.54	0.49	3.15
Dec.	1.85	0.47	0.43	2.76
Total	92.53	22.45	24.60	139.68

During the three months of June, July and August, the river flows constitute 82.32 maf. which is about 58 per cent of the total annual flows.

The canals taken out from the rivers have a diversion capacity of 248,650 cusecs or 0.497 maf. per day. The detail of the capacity of each canal is given in Table No. 3.

The average per day flow of the three rivers, during three months, is about 0.9 maf. During July, the per day flow is about 1.0 maf. At present, there are no means to divert the full flow of the three rivers, during the flood periods. The two dams at Mangla and Tarbela will be able to conserve 5.2 and 8.4 maf. of water respectively. Still large volumes of water will continue to run off into the sea. The present estimate is that till about 1975, 40 maf. of water will continue to flow into the sea.

Rainfall Characteristics

Rainfall is the second natural surface source of water. In the first place, the period of precipitation is not according to the requirements of crops. About 50 per cent of the total rainfall occurs during the two summer months of July and August. Monthly rainfall at a few stations is plotted in Fig. 2[4] and the data are given in Table 4. The rainfall during July and August at a few sites is given in Table No. 5.

TABLE No. 3.—*Data on Principal Canal Irrigation Systems, West Pakistan* (in 1000 Acres).

River	Headworks (2)	Canals	Capacity, cusecs	Operating Since	Gross area Served	Commanded area culturable	Irrigated during 1960/61
						Total	Total
1	2	3	4	5	6	7	8
(1) Peshawar Vale :							
Swat ...	Amandara ...	Upper Swat ...	1800	1915	319	276	328
	Munda ...	Lower Swat ...	800	1890	147	134	188
		Sub-Total ...	2600	...	466	410	516
Kabul ...	Warsak Dam ...	High level left bank ...	45	1962	13	11	...
		Right bank ...	455	1962	125	108	..
		Kabul River ...	450	1890	92	77	68
		Sub-Total ...	950	... ..	230	196	68
		Total Peshawar Vale ...	3550	..	696	606	584
(2) Northern Zone, Indus Plans :							
Jhelum ...	Mangla ...	Upper Jhelum ...	1900 (1)	1915	580	541	539
	Rasul ...	Lower Jhelum ...	5300	1901	1622	1499	1390
		Sub-Total ...	7200	..	2202	2040	1929
Chenab ...	Marala ...	M-R Link ...	2000 (1)	1956	179	160	46
	,, ...	Upper Chenab ...	4100 (1)	1912	1511	1445	890
	Khanki ...	Lower Chenab ...	11500	1892	3703	2987	3078
	Trimmu ...	Rangpur ...	2700	1939	380	347	231
	,, ...	Haveli-Sidhnai ...	5200	1939	1123	1011	1085
		Sub-Total ...	25500	..	6896	5950	5330

1	2	3	4	5	6	7	8
Ravi ...	Madhopur (2)	Central Bari Doab ...	2600	1859	704	642	570
	Balloki ..	Lower Bari Doab ...	7000	1913	1822	1460	1,638
	Sidhnai ...	Sidhnai ...	4500	1887	..	Included in	Haveli Data
		Sub-Total ...	9600	..	2526	2702	2,208
Sutlej ...	Ferozepore (2)	Dipalpur ...	6100	1928	1045	983	577
	Suleimanke ..	Pakpattan ..	6600	1927	1396	1261	1060
	,, ..	Fordwah ..	3400	1927	465	425	260
	,, ..	Eastern Sadiqia ..	4900	1926	1134	937	784
	Islam ..	Mailsi ...	4900	1928	751	688	502
	,, ..	Qaimpur ...	600	1927	45	42	29
	,, ..	Bahawal ..	5400	1927	791	648	476
		Sub-Total ..	31900	..	5627	4984	3688
Panjnad ..	Panjnad ...	Panjnad ...	9000	1929	1505	1339	1139
	,, ..	Abbasia ..	1100	1929	131	110	89
		Sub-Total ..	10100	..	1636	1449	1,228
Indus ..	Jinnah ...	Thal ..	10,000 (3)	1947	1855	1473	749
		Sub-Total ..	10,000	..	1855	1473	749
Indus ...	... ...	Paharpur ...	500	1909	102	100	65
		Sub-Total ..	500	..	102	100	65
Indus ..	Taunsa ..	D.G. Khan ..	8300	1958	730	729	370
		Muzaffargarh ..	7300	1958	721	714	430
		Sub-Total ..	16100	..	1451	1443	800
		Total Northern Zone ..	110900	...	22,295	19,541	16,997

(1) Internal uses.
(2) Madhopur and Ferozepore headworks are in India.
(3) Ultimate capacity 10,000 cusecs, present capacity 6,000 cusecs.

1	2	3	4	5	6	7	8
(3) Southern Zone, Indus Plains :							
Indus	Gudu ..	Pat ..	8300 (4)	1962	766	712 ( )	..
		Desert ..	12900	1962	479	420	309
		Begari-Sind ..	15500	1962	1019	890	268
		Ghotki ..	8500	1962	1004	995	268
		Sub-Total ..	45200	..	3268	3017(6)	1422(6)
Indus ...	Sukkur ..	North West ..	5100	1932	946	928	617
		Rice ..	10200	1932	537	520	570
		Dadu ..	3200	1932	593	549	360
		Khairpur West ..	1900	1932	323	304	257
		Rohri ..	11200	1932	2614	2604	1855
		Khairpur East ..	2700	1932	531	385	334
		Eastern Nara ..	13400	1932	2381	2237	1308
		Sub-Total ..	47700	..	7925	7477	5301
Indus ..	G.M. 7B. ..	Pinyari ..	14400	1955	802	786	232
		Fuleli ..	13800	1955	1065	929	457
		Lined Channel ..	4100	1955	675	487	69
		Kalri Baghar ..	9000	1955	733	604	143
		Sub-Total ..	41300	..	3275	2806	891
	Total Southern Zone	..	134,200	..	14,468	13,300	7,614
	Total Indus Plains (2)+(3)	..	245,100	..	36,763	32,841	23,611
	Total West Pakistan (1)+(2)+(3)	..	248,650	..	37,459	33,447	24,195

(4) Ultimate capacity 8,300 cusecs; present capacity 6,300 cusecs.

(5) New area 509,000 acres; old area 203,000 acres.

(6) Partially irrigated.

TABLE No. 4.—*Rainfall data of selected stations in West Pakistan*
(inches)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total	Rabi	Kharif	July-August
Northern Areas																
Drosh	0.9	0.8	1.7	3.5	3.2	5.4	4.3	2.5	0.9	0.8	1.0	1.2	26.2	15.5	10.7	1.8
Peshawar	0.4	0.4	0.6	1.5	1.7	2.7	1.8	1.7	0.4	1.7	1.8	0.5	15.2	7.3	7.9	3.5
Bannu	0.1	0.1	0.4	0.9	1.1	1.0	1.2	0.6	0.9	2.6	2.0	0.9	12.7	4.5	8.2	4.6
Gilhit	0.2	..	0.1	0.3	0.3	0.9	1.0	1.9	0.4	0.5	0.4	0.2	6.2	1.8	4.4	0.9
Potwar Plateau																
Rawalpindi	0.9	0.5	0.9	2.4	2.4	3.0	1.8	1.4	1.9	9.2	10.1	3.5	37.8	10.1	27.7	19.3
Murree	2.0	0.8	2.0	4.5	6.0	5.0	4.1	2.3	4.2	14.1	13.7	5.2	59.9	21.3	43.6	27.8
Indus Plain Northern Zone																
Lahore	0.2	0.1	0.5	1.0	0.8	0.9	0.7	0.6	1.7	4.9	5.0	3.2	19.8	3.5	16.1	9.9
Sialkot	0.9	0.5	1.0	0.8	1.7	1.6	0.8	0.7	0.5	2.2	10.6	9.8	30.5	6.5	24.6	12.8
Lyallpur	0.1	0.1	0.2	0.6	0.8	1.0	0.5	0.4	1.0	3.9	3.9	1.1	13.6	2.8	10.8	7.8
Multan	0.5	0.1	0.2	0.4	0.5	0.6	0.3	0.4	0.4	1.9	1.3	0.8	13.4	2.3	5.1	3.2
Khanpur	0.1	0.1	0.1	0.2	0.4	0.4	0.1	0.4	0.2	1.8	1.5	0.4	5.7	1.3	4.4	3.3
Indus Plain Southern Zone																
Jacobabad	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.3	1.7	1.0	0.1	4.1	0.9	3.3	3.7
Hyderabad	0.1	..	0.1	0.1	0.1	0.1	..	0.1	0.2	2.8	1.7	0.7	6.0	0.5	5.5	5.8
Karachi	..	..	0.2	0.4	0.5	0.4	0.1	...	0.3	3.8	2.0	0.7	8.4	1.5	6.9	5.8
Mekran Coast, Baluchistan																
Lasbela	...	..	0.6	0.3	0.9	1.0	0.7	0.5	0.5	2.7	0.5	0.5	7.2	2.8	5.4	3.2
Dalbandin	...	0.1	0.6	1.0	1.8	0.5	0.2	0.1	..	0.3	..	...	4.6	4.0	0.6	0.3
Pasni	...	0.1	0.4	1.8	1.4	0.3	0.2	..	0.2	0.4	0.1	...	4.9	4.0	0.9	0.5
Baluchistan Northern Area																
Fort Sandeman	0.1	0.4	0.5	0.8	1.1	1.4	1.0	0.8	0.5	2.0	1.9	0.3	10.8	4.3	6.5	3.9
Quetta	0.1	0.2	1.0	1.5	1.8	1.8	0.6	0.3	0.1	1.8	0.1	0.1	9.4	6.4	3.0	1.9
Kalat	...	0.2	0.8	2.0	1.8	1.5	0.7	0.2	..	0.3	0.4	..	5.8	6.3	1.6	0.7

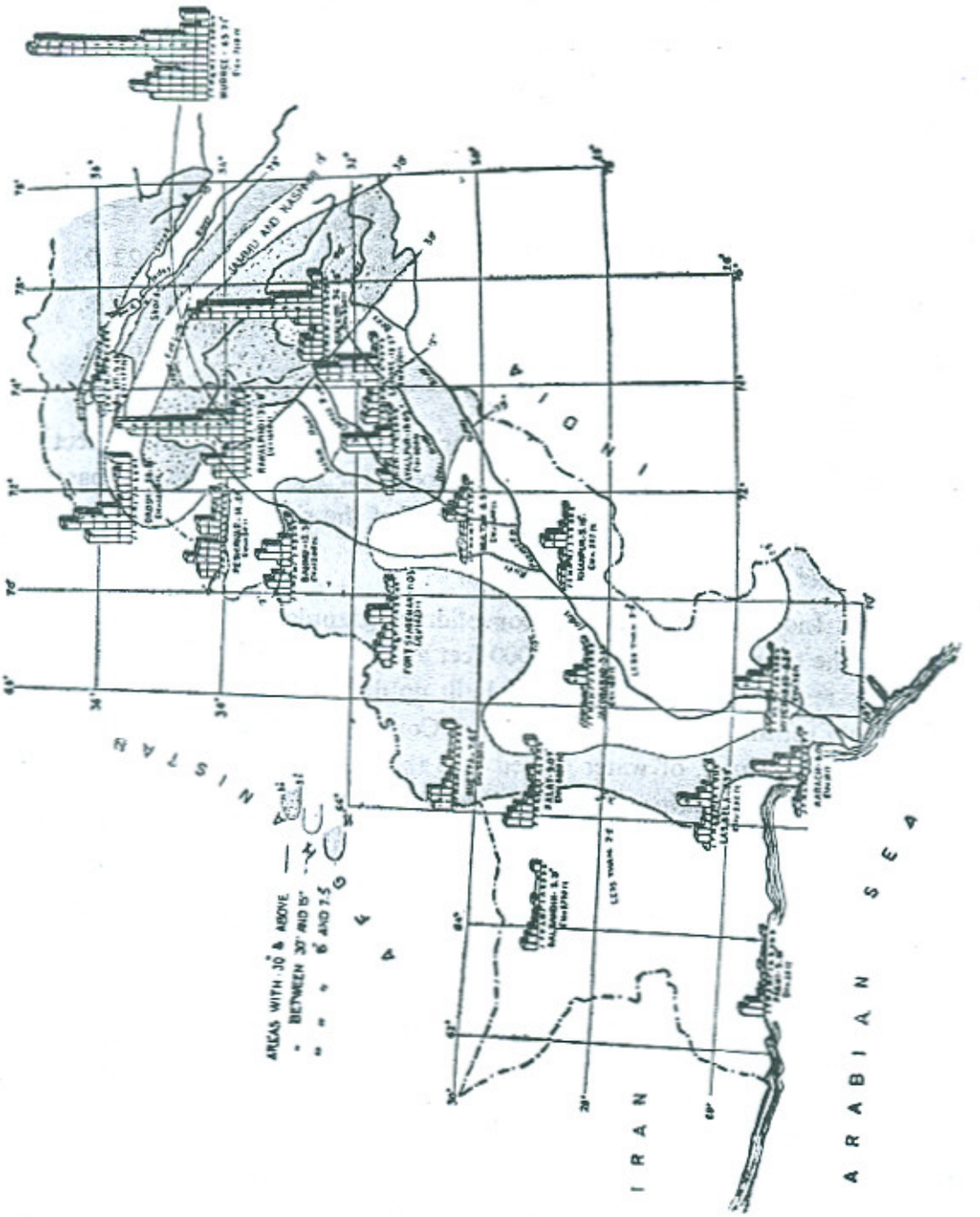


Fig. 2. Mean Monthly Rainfall

TABLE No. 5.—*Percentage of total rainfall in inches during July and August*

Sites	Total per year	During July and August	% of total during July and Aug.
Rawalpindi	37.8	19.3	51.3
Lahore	19.8	9.9	50.0
Sialkot	30.5	12.8	42.0
Lyallpur	30.56	7.8	57.2
Multan	14.4	3.2	22.2
Hyderabad	6.0	5.8	96.8
Karachi	8.4	5.8	69.0

This high intensity of rainfall, during the two summer months, affects the demand of canal water. Some canals are closed for short duration to pass high floods. These factors also help in the run-off of the river flows to the sea.

Ground water

The Indus Plains overlie unconsolidated granular, soft formations. Its depth on the average is more than 1000 feet and is saturated to brim with water. This huge reservoir of water has been built up during the last several centuries. It has been estimated by the World Bank Consultants[5] that in the pre-irrigated periods about 10 maf. of water seeped into the 40m. acres of the lands. The recharge to the formation with the development of the canal irrigation has continued to increase.

The present estimates are that nearly 49 maf. of water percolates from various surface resources. Harza Engineering Company[1] and the Consultants of the World Bank have put forth estimates of recharge from various surface resources. Estimate of recharge before 1970 and after 1970 by Harza are as given in Tables 6 and 7, respectively. With a diversion of 83.5 maf. before 1970, a recharge equal to 36.4 maf. was estimated. Now with the increased division going up to 92.1 maf. and with new links, the recharge estimate is 46.2 maf. of which 32.6 maf. occurs in the northern zone and 13.6 maf. in the southern. The diversion in Sind has increased to about 39 maf. so that seepage in the area has proportionally increased to about 17 maf.

A similar estimate was worked out by the World Bank Consultants. They estimated a recharge of 49 maf. by 1975. The detail of their estimates from various sources is explained in Fig. 3. Thus presently about 49 to 50 maf. of water recharges into the aquifer lying generally under the irrigated areas of the Indus plains.

TABLE No. 6—*Estimate of recharge, prior to* 1970 *according to Harza and World Bank Consultants. Values in Maf.*

	Harza Estimates			World Bank Estimate for W. Pak.
	for W. Pak.	Northern area	Southern area	
1. Total Diversion into Canals	83.5	48.2	35.3	79
2. Percolation from Rivers	4.0	3.0	1.0	6.0
3. Percolation from Canals	20.0	11.5	8.5	17.0
4. Percolation from Watercourses	3.0	1.8	1.2	3.0
5. Percolation from Fields	8.2	4.8	3.4	7.0
6. Percolation from Rainfall	1.2	1.0	0.2	—
7. Total percolation	36.4	22.1	14.3	33.0

TABLE No. 7—*Estimates of recharge after the implementation of Indus Basin Treaty, Harza estimates. Values in Maf.*

	W. Pak	Northern area	Sorthern area
Total Division into Canals	92.1	61.0	31.1
Percolation from Rivers	3.1	1.9	1.2
Percolation from Rainfall	2.5	2.3	0.2
Percolation from Canals	24.2	16.8	7.4
Percolation from Watrcourses	4.4	3.1	1.3
Percolation from Fields	12.0	8.5	3.5
Total Percolation,	46.2	32.6	13.6

Hunting firm estimated the addition to ground water by considering the seepage from watercourses, minor and branch canals, main canals and contribution from rainfall. They found as per detail in Table 8, a recharge equal to 1.425 cusecs per sq. mile with water table 7 feet below surface. Thus from a perennial area of say 9 million acres, the drainage surplus in Sind is 14 maf. including the irrigated areas of Gudu and G.M. Barrage, the estimate of seepage equal to 17 maf. is thus not too much out of proportion.

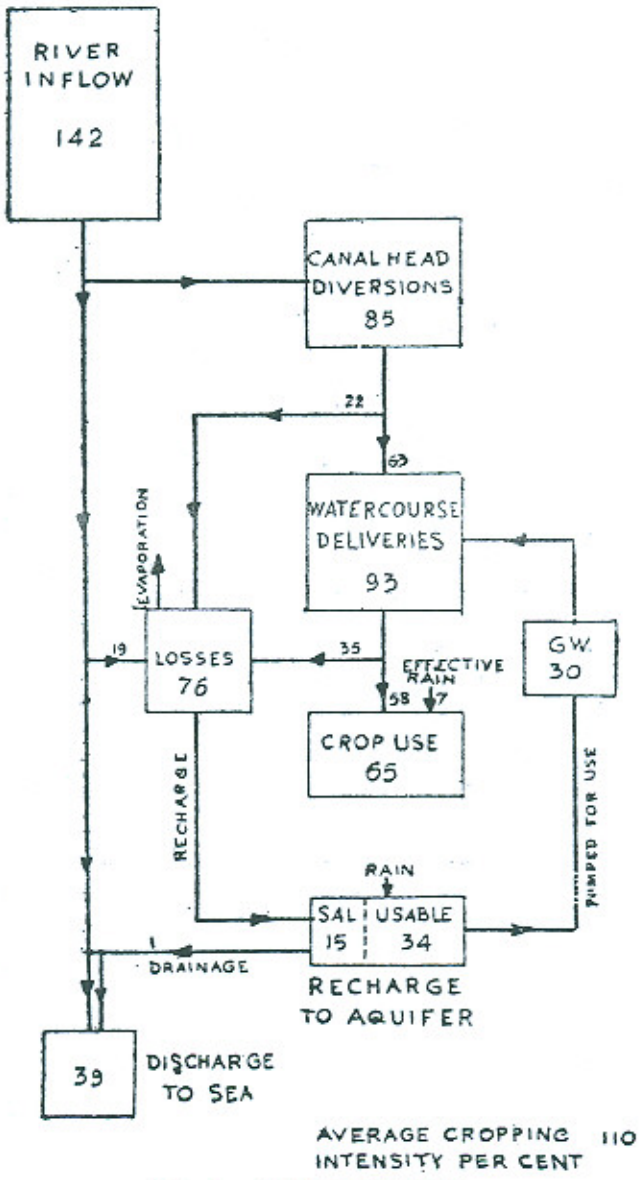


Fig. 3. World Bank Data

TABLE No. 8.—*Contribution to Ground water in cusecs per sq. mile for Sind area worked out by Hunting. All values are in Maf.*

Main items of contribution	W. Table at 7 ft. depth	W. Table at 4 ft. depth
From Watercourse	1.005	1.005
From Main and Branches	0.350	0.350
From Main Canals	0.303	0.303
From Rainfall	0.064	0.070
Sub-Total :	1.722	1.726
Non-beneficial evaporation & crop evapotranspiration	0.297	0.376
Total addition to Ground water	1.425	1.352

Disposal of this huge input of water :

About 20 years ago, this large volume of seepage was going waste, causing waterlogging and salinity.

The disposal of this infiltration has been by evaporation. evapotranspiration and sub-soil flow. In the arid and semi-arid zones of West Pakistan evaporation from free water surface (f.w.s), and from soils, is considerable. The free water surface evaporation (f.w.s) has been found to vary between 3 cusecs to 7 cusecs per square mile.

The low order is for cooler areas and high order for Jacobabad, Sibi, Darwat and areas near Karachi. For a large area of the plain, it is about 5 cusecs per square mile. In Fig. 4 monthly free water surface evaporation, for a number of sites in West Pakistan, is illustrated. The evaporation contours are also drawn.

The evaporation from bare soil with water table at different depths is also significant. Investigations conducted at Niazbeg[7] Field Station gave the order of evaporation from bare soil for different depths of water table as shown in Fig. 5. The soil evaporation with water table at 10 feet below surface was about 3 to 5 per cent of the free water surface evaporation. Fireman[8] has studied the evaporation with water table at 20 feet depth. His results are plotted in Fig. 6.

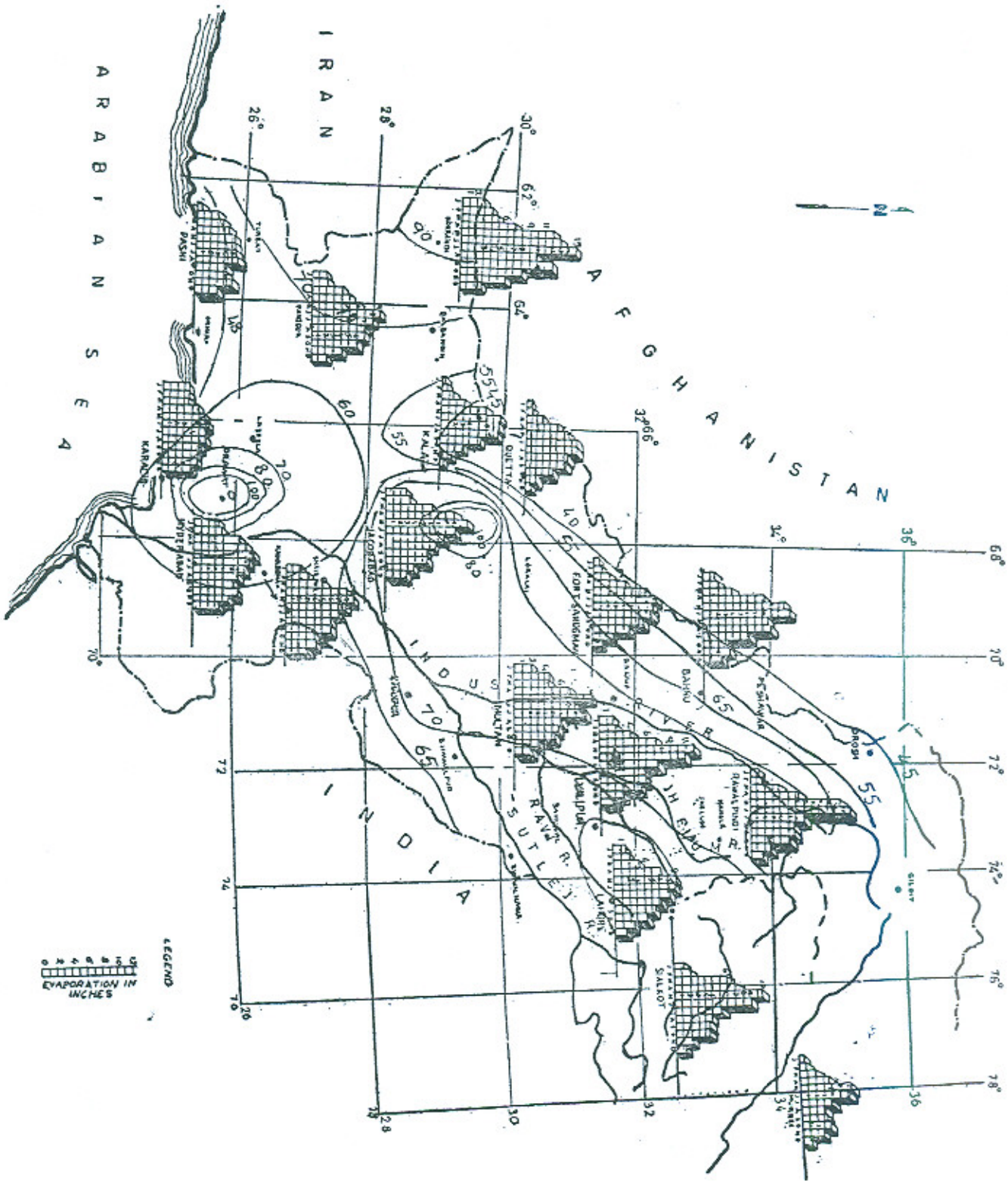


Fig. 4. F.W.S. Evaporation (calculated) Annual Evaporation contours, Monthly Evaporation at selected sites

Growth of vegetation causes evapotranspiration. Under certain conditions it is more than the free water surface evaporation. Weeds, for instance, transpire large volume of water. These can grow even in waterlogged areas. Blaney[10] and Thomson[11] have put forth results of their observations on the increased

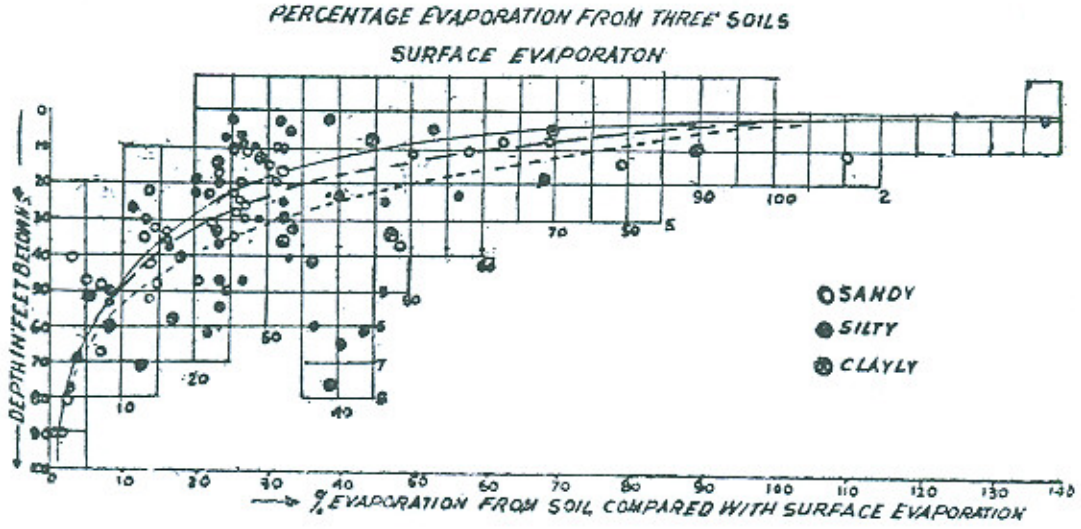


Fig. 5

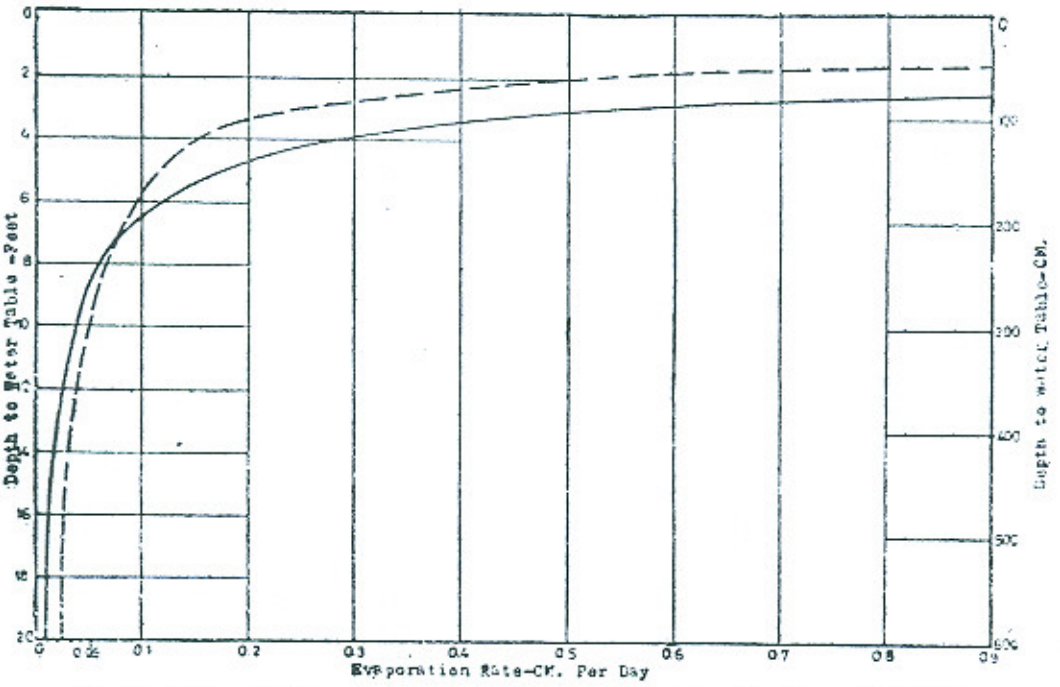


Fig. 6. Theoretical and Experimental Rates of Evaporation from Soil Columns having different water table depths

amount of water, transpired by different kinds of weeds with rising water table. These results are given in Figs. 7 and 8. Fig. 7 is from Blaney which shows the result of investigations conducted for several years. The points A, B, C, & D represent the mean values of several years of studies.

Some results of investigations[7] with cotton, sugarcane and wheat crops are given in Table 9. The evapotranspiration is more than evaporation from a free water surface. This is the case for cotton crops with water table up to 9 feet depth, sugarcane up to 8.5 feet depth and for wheat up to 7 feet depth. The sub-soil flow is another means of disposal of this infiltration. Much is not known at present about this component.

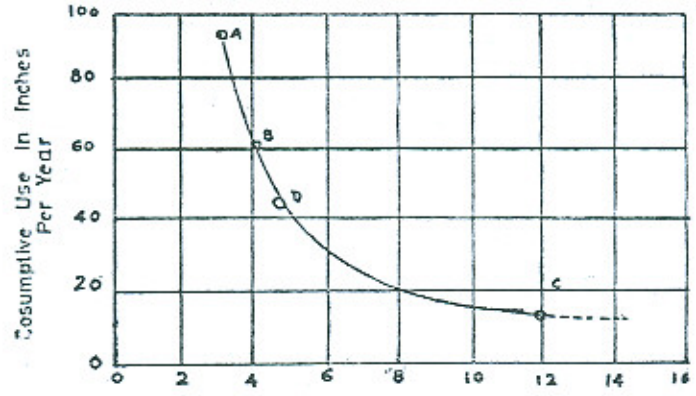


Fig. 7 Distance of Water Table below ground surface in feet, Results of Balney

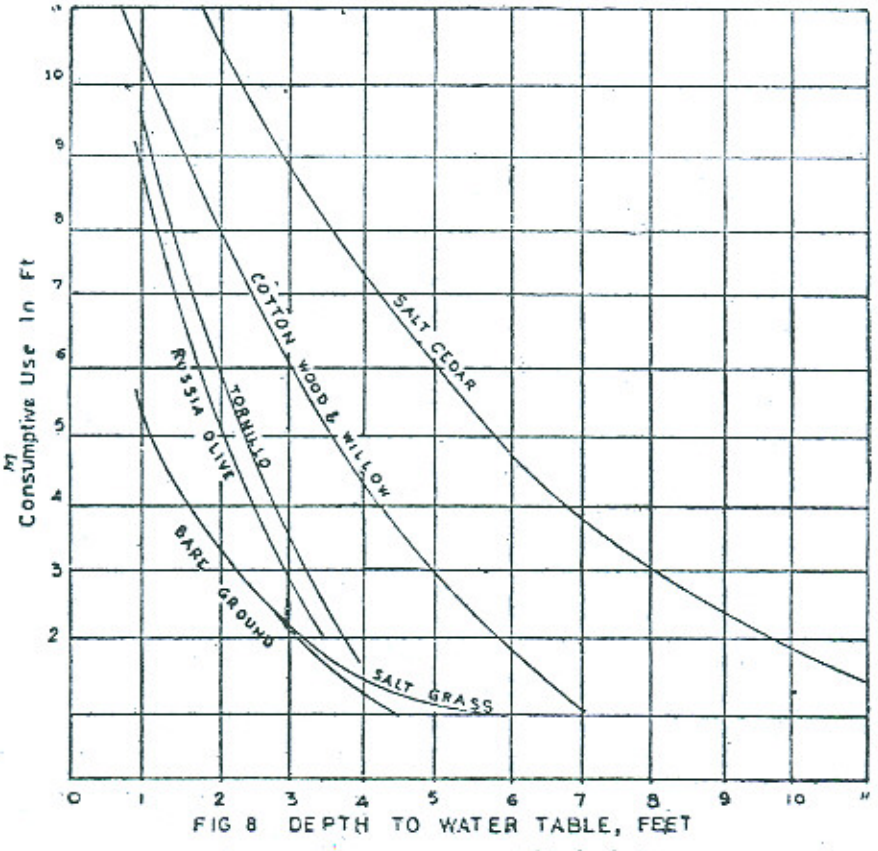


Fig. 8. Depth to water table in feet

TABLE No. 9.—*Ratio of total evapotranspiration, E_t to free water surface evaporation, E_v or E_t/E_v for different crops w. r. t. different water table positions.*

Crop	Growth period	Type of soil	Water Table at Different Depths in ft.										
			2.5	3.0	4.0	5.0	6.0	7.0	8.0	8.5	9.0	11.0	14.0
Cotton	May to Dec.	Clayey	... 1.95	...	1.67	1.45	1.33	1.25	1.20	...	1.15	..	...
		Silty	... 2.19	...	1.86	1.59	1.41	1.27	1.20	...	1.14	...	...
Sugarcane	March to Jan.	Clayey	... ...	2.90	1.61	...	1.28	..	..	1.04	...	0.92	0.86
		Silty	... ...	...	1.55	...	...	...	...	1.19	...	0.98	...
Wheat	Mid Nov. to May	Clayey	... ...	1.74	1.51	1.34	1.19	1.06	0.94	...	0.85	...	...

Saline and Sweet Zones of Ground water.

Each doab of the Punjab has two perennial line sources, feeding the underground formation. This seepage during the past centuries has continued to dissolve the salts deposited during the building of the alluvium, and create zones of fresh water. The ground water salinity of zones receiving the recharge thus increased. The accumulation of seepage water and a slow process of its disposal by evaporation seems to be the cause of the present saline ground water in the doabs. The existing zones of saline ground water in the Punjab are between 400 to 600 each above sea level. The salts of the sea water could not rise to such heights in the centre of each doab only and exist at such elevations under the pressure of sub-soil water. Herberg[27] & Ghyben[28] have proved that a head of fresh water pushes down the saline water. Mathematically, it was shown that one foot head of fresh water could push down the interface of saline water by forty times. Many practical examples are available to prove the theory.

Khulna and Barisal in East Pakistan, are less than 10 feet above sea level. The formation of these areas has no saline water within the explored depth of 1000 feet. Dacca is 25 feet above sea level and tubewells in this area are 600 feet deep, drawing fresh ground water. The Sunderban Forests grow on lands, 2 to 5 feet above sea level. Thus there are ample reasons to believe that the original saline water, must have been washed off, by the head of fresh water, and the existing saline water accumulation is a result of removal of the salts deposited in the formation. Actually the pre-irrigation depth of ground water generally receiving the recharge, in the centre of the four doabs, was between 65 to 100 feet as shown in Table 10.

TABLE No. 10—*Pre-irrigation Deepest position of Ground water.*

Sites	Location around Area	Depth of Ground water in feet
Thal Doab	Greater Thal	65
Chej	Sargodha	75
Rechna	Lyallpur	90-100
Bari	Sahiwal	70

Another proof of this conception is the existence of saline ground water pockets within the flood plains. Their small extent and occurrence at various depths, within the zones of sub-soil flow, suggest that these were deposited along with the alluvium. It has not been possible to wash them off by the sub-soil flowing water. Their existence is a result of obstruction of the impervious medium hindering the sub-soil flow. Their location is invariably close to the clay deposits which exist at various depths without any regularity.

With the start of irrigation and increase in percolation, the seeping water enveloped the saline water zone on all sides. The present conditions in the Punjab are illustrated by three cross sections (see Fig. 9) showing the panoramic view of the location of saline ground water zones in the Indus formation. At a few sites, a fairly sharp interface of saline and fresh water exists. Deeper waters are more saline followed by an enveloped of comparatively less saline water and fresh water, in turn. In Table 11, the extent of the area possessing deep ground water with soluble salts up to 1000 ppm., and spread in 19.63 m. acres out of a total of 30.72 m. acres of the Punjab zones is put forth. These data are reproduced from FAO Pakistan Symposium[25] of 1964.

TABLE No. 11—*Areas and percentage of areas underlain by water of specified dissolved solids, FAO Seminar, 1964, salts in PPM.*

	Areas in 1000 acres						
Sites	Areas	1000 ppm.	% total	1000-2000 ppm.	% total	above 2000 ppm.	% total
Thal Doab	7898	5018	63.5	1606	20.2	1274	16.3
Chaj Doab	3228	2353	73.0	284	8.8	591	18.3
Rechna Doab	7040	5331	76.0	902	12.9	807	11.6
Bari Doab	8050	5694	70.6	1246	16.7	1110	13.8
Bahawalpur	4500	1234	27.4	506	11.3	2760	61.5
Total	30,716	19,630	64.0	4,544	14.8	6,542	21.4

Similar information has been put forth by Tipton and Kalmbach[3], reproduced in Table 12.

TABLE No. 12—*Areas of Good and Bad Quality Ground water in the Punjab. Values are in Million Acres*

Doab	Area	Area possessing Ground water with salts more than 1000 ppm.	Area with salts less than 1000 ppm.	% total
Rechna Doab	4.7	0.70	4.0	85.5
Chaj Doab	2.0	0.42	1.58	79.0
Thal Doab	5.3	1.48	3.82	72.0
Bari Doab	4.40	1.76	2.64	60.0
Total	16.40	4.36	12.04	73.5

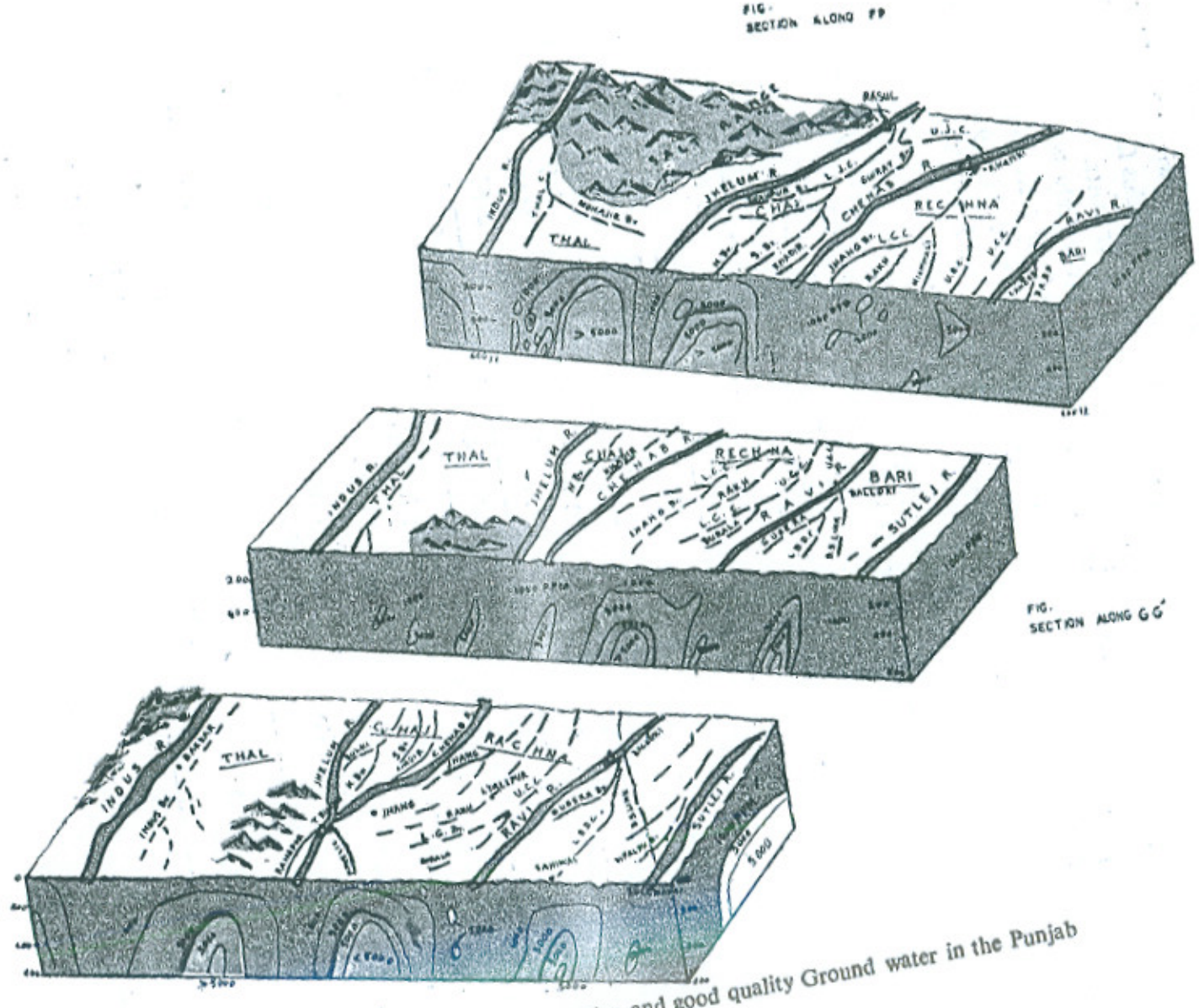


Fig. 9. Panoramic View of Saline and good quality Ground water in the Punjab

In the four doabs of the Punjab in an area of 16.4 m. acres deep ground water containing 1000 ppm. of salts exist in an area of 12.04 m. acres constituting about 73.5% of total. Another 4.36 m. acres contain ground water with salts more than 1000 ppm.

In the White House report of 1964 by Revelle,[12] an estimate of the river water diversions into the canals of the Punjab and Bahawalpur was put forth. It was estimated that out of the 45 million acres feet of water let into the canals, that reaching the fields constituted 24.3 maf. Out of this the water distribution on non-saline ground water area was 18.6 maf. and on saline ground water area was 5.7 maf. An areas 18.4 m. acres had non-saline and 5.6 m. acres had saline ground water. These estimates are explained in Fig. 10.

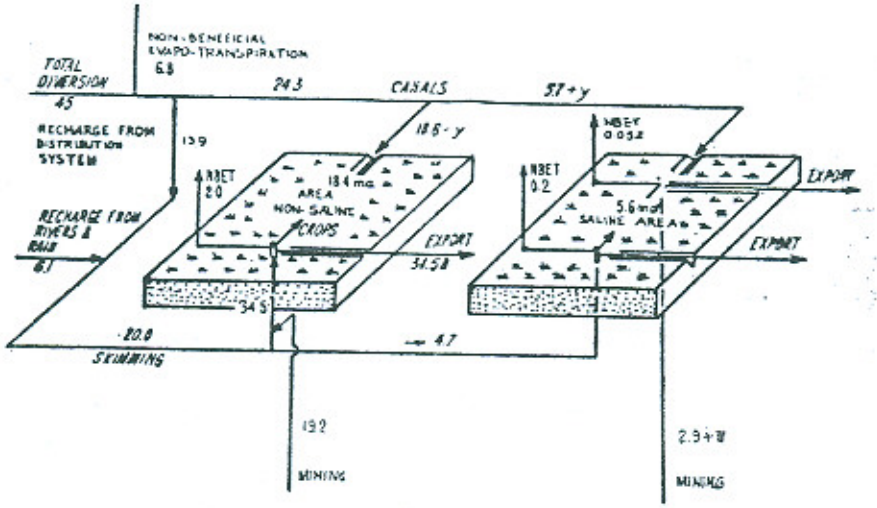


Fig. 10. Schematic Diagram for Punjab and Bahawalpur Region, canal diversions and withdrawals from ground water (flows in maf. per year)

The Sind area has been investigated by Hunting Technical Services.[6] Detailed studies were conducted to determine the location and depth of ground water of varying qualities. The results of their investigations are put forth in Table 13. Gudu and Sukkur Barrage possess deep useable ground water. An area of 2.02 m. acres possesses ground water bearing total soluble salts up to 750 ppm. within a depth of 200 feet. Similarly another 0.842 m. acres possess souble salts up to 1500 ppm. within the same depth of the formation. In the Gudu and Sukkur Barrage Command on its left bank side about 25 per cent of the area and on the right bank side about 20 per cent of the area possess deep usable ground water. The whole of 3.316 m. acres of G.M. Barrage are included in the group of saline ground water.

Another latest evaluation of sweet, intermediate and saline ground water areas for whole of West Pakistan is by the World Bank Consultants.[5] Their estimates are put forth in Table 14 which show that in an area of 14.22 million acres, deep ground water exist possessing dissolved salts up to 1000 ppm. The

TABLE No. 13—*Regional distribution of Ground water of various Salinities, ppm.*
(1,000 acres)

Command	Depth) (feet)	0-750	750-1500	1500-2500	2500-4500	above 4500	Total
Gudu Left Bank ..	0-200	382	56	54	62	406	960
	0-300	319	53	51	83	454	960
	0-400	142	145	112	94	467	960
	0-500	70	136	106	72	576	960
Gudu Right Bank ..	0-200	329	104	137	257	1,313	2,140
	0-300	252	163	91	181	1,453	2,140
	0-400	86	273	69	212	1,500	2,140
	0-500	61	112	229	177	1,561	2,140
Sukkur Left Bank ..	0-200	1,143	446	235	335	4,126	6,305
	0-300	809	525	153	261	4,557	6,305
	0-400	361	234	545	327	4,838	6,305
	0-500	253	138	278	507	5,129	6,305
Sukkur Right Bank ..	0-300	164	236	115	161	1,520	2,196
	0-300	147	141	82	192	1,634	2,196
	0-400	100	149	82	180	1,685	2,196
	0-500	44	115	104	174	1,759	2,196
Ghulam Mohammad Left Bank ..	—	—	—	—	—	2,544	2,544
Ghulam Mohammad Right Bank..	—	—	—	—	—	772	772
Total	0-200	2,018	842	541	835	10,681	14,917
	0-300	1,527	882	377	717	11,414	14,917
	0-400	689	801	808	813	11,806	14,917
	0-500	428	501	717	930	12,341	14,917