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Pakistan
Special Agriculture Sector Review

(In Five Volumes)

Volume II: Irrigation and Drainage

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General Agriculture Division
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CURRENCY EQUIVALENTS

Rs 9.90	=	US$ 1.00
Rs 1.00	=	US$ 0.10
Rs 1.0 million	=	US$101,010

WEIGHTS AND MEASURES

English/US Units		Metric Units
1 foot (ft)	=	30.5 centimeters (cm)
1 yard (yd)	=	0.915 meters (m)
1 mile (mi)	=	1.609 kilometers (km)
1 acre (ac)	=	0.405 hectare (ha)
1 square mile (sq mi)	=	259 ha
1 cubic ft (cu ft)	=	0.028 cubic meters (m^3)
1 cubic yd (cu yd)	=	0.765 m^3
1 acre-foot (ac-ft)	=	1,234 m^3
1 cu ft/sec (cusec)	=	0.028 m^3/sec
1 pound (lb)	=	0.454 kilograms (kg)
1 long ton (lg ton)	=	1,016 kg (1.016 metric tons)

Pakistani Units		English Units		Metric Units
1 maund (mds)	=	82.3 lb (.0367 lg ton)	=	37.3 kg (.0373 m tons)
26.8 mds	=		=	1.0 m ton
27.2 mds	=	1.0 lg ton		

GLOSSARY OF ABBREVIATIONS

ADBP - Agricultural Development Bank of Pakistan
CCA - Culturable commanded area
GOP - Government of Pakistan
HYV - High-yielding variety
IACA - Irrigation and Agriculture Consultants Association
IBP - Indus Basin Project
ISS - Indus Special Study
LBOD - Left Bank Outfall Drain
LIP - Lower Indus Project
MAF - Million acre-feet
NWFP - North West Frontier Province
SCARP - Salinity Control and Reclamation Project
UNDP - United Nations Development Programme
WAPDA - Water and Power Development Authority
WMC - Water Management Cell, WAPDA

GLOSSARY OF ACRONYMS

Chak	-	Area served by a watercourse from an irrigation outlet.
Doab	-	Area between two rivers.
Kharif	-	The hot (summer) season and main rainy period (mid April through mid-October).
Paddy	-	Growing or threshed, unmilled rice.
Patwari	-	Local watercourse official.
Rabi	-	The cool (winter) season (mid-October through mid-April).
Warabundi	-	Schedule for water distribution to farmers on a watercourse

GOVERNMENT OF PAKISTAN
FISCAL YEAR

July 1 to June 30

This volume of the report is based on the findings of the Irrigation and Drainage Review Mission which visited Pakistan in February/April 1974. The mission consisted of Messrs. C. M. Bolt, A. J. Blackwood, H. T. Chang, W. H. Edwards, S. El Serafy, M. Fireman (Bank), F. Locher, H. Parkinson and T. A. Samuels (consultants).

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

Table of Contents

Page No.

ANNEXES

1. Canal Commands, Development Modes and Water Distribution
2. ISS Action Program Status
3. Preliminary List of Projects
4. UNDP Indus Basin Planning Project

TECHNICAL NOTES

Included in Volume II:

Technical Note No. 1: The Indus Basin Surface Water System
Technical Note No. 2: Soils and Groundwater
Technical Note No. 3: Tubewell Development

MAPS

11699 - Major Canals and Reservoirs of the Indus Basin in Pakistan
11827R- Canal Commands

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

I. INTRODUCTION

1.01 One of the most significant aspects of Pakistan's fluctuating economic progress since 1970 has been the generally disappointing performance of the agriculture sector. National crop production has not continued to grow at the rate achieved in 1965-70; it has not even kept pace with the increase in population. Among the actions called for to promote a renewed upsurge in farm output in Pakistan, and to reap full benefits from the massive investments made under the Indus Basin and the Tarbela Projects, the Government of Pakistan (GOP) has recognized that high priority must be given to the acceleration of its program to minimize the on-farm constraints caused by waterlogging and widespread salinity of the soil. The Provincial Governments of Baluchistan, North West Frontier, Punjab, and Sind also realize that, if crop yields are to be raised above the generally low present level, their engineers, agriculturalists and farmers alike will have to join forces to reduce soil salinization and to ensure that limited irrigation water supplies are distributed and utilized effectively.

1.02 A Bank Irrigation and Drainage Review mission visited Pakistan in February/April 1974 to observe the results of recent activities in irrigated agricultural and water resource development, to review plans for future development and to identify specific projects, as well as technical assistance needs for the preparation of plans and projects which might be appropriate for World Bank assistance in water resource development. Based on the findings of the mission, and on information which has subsequently become available, Volume II examines Pakistan's overall irrigation and drainage development situation and identifies the significant issues constraining progress. Some of the factors in the selection of priority water development projects suitable for financing by the World Bank are considered, and Volume II includes Technical Notes which contain supporting analyses on key aspects and issues of irrigated farming development in Pakistan. Water management on water courses and farms and related institutional issues are discussed in detail in Volume III.

II. IRRIGATION IN PAKISTAN

A. The Irrigated Agriculture Setting

2.01 Most of Pakistan's agricultural production comes from about 30 million acres (M ac) of land cropped annually under irrigation in the Indus Basin. This farmland accounts for virtually all of the nation's production of paddy rice (3.4 M tons) and sugarcane (19.5 M tons), 90 percent of the wheat (6.6 M tons), and 95 percent of the cotton (2 M tons) 1/. The climate of the Indus Plains enables farmers to obtain two crops under irrigation each year. In kharif (the hot season between April and October, including the southeast monsoon), rice (3.5 M ac), cotton (5 M ac), sugarcane (1.5 M ac) and maize or grain sorghum (2.6 M ac) are grown. During rabi (the cool, dry season between October and April), wheat, oilseeds and gram can be grown. Since wheat is the most profitable crop at present prices and with existing technology, it is grown on suitable land wherever possible, given adequate water. As a result, about 40 percent of the irrigated land (10 M ac) is under wheat.

2.02 Much of the advance made since the mid-1960s in Pakistan's farm production was due to the development of irrigated crop technology. The large-scale introduction of high-yielding dwarf varieties of wheat, beginning in 1967, gave rise to increases of about 50 percent in irrigated wheat yields. New rice varieties, increasingly grown since 1968, brought about production increases of some 70 percent. Output of cotton has risen about 40 percent since 1967. These increases were influenced by additional farm inputs and favorable water supplies from canals and tubewells.

2.03 By world standards average crop yields in Pakistan's irrigated agriculture are low, partly due to constraints which are beyond the farmers' capabilities to remove without institutional aid. Among the most difficult problems that the great majority of farmers have to contend with are:

(a) the increasingly adverse soil conditions reflected in the gradual spread of both waterlogging and salinization, and

(b) untimely, unpredictable and often inadequate on-farm irrigation water supplies (see Volumes I and III).

In many areas water tables have gradually risen, largely as a result of uncontrolled deep seepage of water from canals for periods of a century or more. Salts have slowly accumulated to harmful levels in the topsoil due to two causes: firstly, as a result of the short-sighted, traditional practice of applying frequently inadequate water supplies to too much land; and secondly, because of the continuous capillary rise and subsequent evaporation of saline groundwater in the surface layers of fallow land, particularly where underlying water tables have risen. There are two key, large-scale physical deficiencies within deteriorating irrigated areas; (a) the shortage of canal water at the farm level to provide for critical mid-summer crop irrigation requirements, as well as to dissolve and remove harmful, excess soil salts, and (b) the lack of sub-surface drainage for prevention of waterlogging and for harmless disposal of highly saline field drainage effluent. These contraints cannot be overcome by the unaided efforts of farmers alone; they can be removed by public investment in the enlargement of canal capacities to distribute plentiful river flows in

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1/ 1972/73 data.

summer, and in the construction of drainage systems for the control and disposal of harmful groundwater and salt.

B. Surface Irrigation, Drainage and Groundwater Development

2.04 Canals. The present irrigation canal systems, as distinct from the ancient inundation canal lands, cover a gross area of approximately 38 M ac and have been developed over a period of about a century. Until recently, canal irrigation throughout Pakistan was entirely dependent on the diversion of run-of-river discharges which varied from high, though unpredictable levels between June and September to the lowest flows in February; prior to 1967, no storage reservoirs had been constructed in Pakistan to provide seasonal regulation of these widely varying discharges.

2.05 The existing canals, totalling about 38,000 miles in length, supply 42 separate canal commands ranging in size from 40,000 ac to 3 M ac (see Annex 1, Map 11827R and Technical Note No. 1). Along the Indus and its major tributaries, the Sutlej, Ravi, Chenab, Jhelum, Kabul and Swat, river levels are controlled and water is diverted into the main canals by means of 20 barrages and weirs. The canals command about 33 M ac of culturable land (including some presently uncultivated areas), of which about 29 M ac are cropped under irrigation each year, some being double cropped. About 18.5 M ac, or two thirds of the irrigated areas, have water rights for year-round (perennial) supplies. The remaining 10.8 M ac generally receive non-perennial canal water only in kharif when river flows are generally more plentiful (Annex 1, Table 1). About 140 million acre-feet (M ac-ft) of water is available annually in the Indus, Jhelum and Chenab Rivers for use in Pakistan. Of this amount, about 60 M ac-ft is diverted at the barrages into the canals in kharif; depending largely on available river flows, about 28 M ac-ft enters the perennial canals in rabi. The culturable commanded area (CCA) presently irrigated annually within the Provinces includes about 0.2 M ac in Baluchistan, about 0.7 M ac in North West Frontier, about 19.7 M ac in Punjab, and about 8.9 M ac in Sind.

2.06 To supplement the inadequate flows of the eastern tributaries of the Indus, the prodigious Upper Jhelum and Upper Chenab Canals (UJC and UCC) were built more than 60 years ago, with capacities of 8,000 cubic feet per second (cusec), enabling surplus flows in the Jhelum and Chenab Rivers to be transferred to the water-short Ravi and Sutlej valleys (see Map 11699). Three huge, additional link canals were built between 1950 and 1958 to further supplement the flow of the eastern rivers; the Marala-Ravi (MR) Link Canal from the Chenab to the Ravi, the BRBD Link from the Chenab to the west bank of the Sutlej and the Balloki-Suleimanke (BSI) Link from the Ravi to the Sutlej river (see Map 11699).

2.07 In addition to the link canals transferring bulk water supplies westwards across the Punjab, many of the main irrigation canals serving the irrigated areas are large by world standards; 15 of them have capacities of over 10,000 cusec. The main and branch canals are sufficiently controlled by structures to enable them to carry flows satisfactorily from 10 percent more to 60 percent less than their designed full capacity. The distributary canals, which have capacities of up to 200 cusec, feed the minor canals of 5 cusec or more. The minors supply water through fixed irrigation outlets to watercourses of between 1 and 4 cusec capacity, which deliver irrigation supplies to each farm within their commanded areas, generally between 150 and 600 ac. The distributary canal systems are designed so that each irrigation outlet provides its watercourse with an almost consistent discharge, until the distributary flow drops to about three-fourths of full capacity. When this flow cannot be maintained due to shortage of supply in the main canal, a system of closure of distributaries is put into effect by rotation, so that available supplies are equitably shared between the distributary canal commands. Under this system, a minor canal and its irrigation outlets to watercourses can either operate at about full capacity, or be closed; there is no intermediate stage of regulation. The irrigation outlets provide a discharge - often silt-laden - proportional to the farming area commanded by each watercourse (the "chak"). Most cultivators have a fixed time, proportional to the area of their holdings within the chak, in which they are entitled to take the whole flow in the watercourse in turn during its period of discharge (see Technical Note No. 1).

C. Drainage

2.08 In common with many irrigated areas developed in the earlier part of this century, little drainage has been provided in the canal commands other than improved natural channels. Roads, railways and canals were usually aligned across the natural drainage lines and have aggravated surface drainage problems. While some major projects to improve surface drainage are in progress in Sind, and to a lesser extent in the Punjab, surface drainage has been largely neglected over the last several decades.

2.09 The hydrological balance of the Indus Basin has been significantly modified over the past century as a result of the diversion of most of the river flows into canals, the subsequent canal seepage losses (particularly from unlined canals), and inadequate natural drainage. Unchecked seepage to the groundwater aquifer has resulted in the continuous rise of the watertable throughout the irrigated area, from an original depth of over 50 ft to less than 20 ft in the central part of the "doabs" 1/, and to less than 10 ft in many places. This has produced waterlogging of surface soils over wide areas, and has been a contributory cause of salt accumulations at or near the surface due to capillary rise of moisture from shallow watertables, followed by evaporation (see para 2.03 and Technical Note No. 3).

1/ Areas between the rivers.

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1/ Areas between the rivers.

also provide more timely water supplies for irrigation in some of the northern areas.

F. The Indus Basin Project Works

2.13 The new IBP link systems include five immense canals, the TSMB, RQBS, BS II, CJ and TP Links, having an aggregate capacity of about 70,000 cusec, and which now supplement the earlier link canals (Map 11699). The new IBP link systems' barrages, most of which are about a mile long, were built at Sidhnai on the Ravi, at Rasul on the Jhelum, at Marala and Qadirabad on the Chenab, and at Chasma on the Indus; in addition, a mile-long, inverted syphon was constructed under the Sutlej at Mailsi. The vast Mangla dam, capable of storing 5.7 M ac-ft of kharif water on the Jhelum for release in drier months, was completed a year ahead of schedule, in 1967. The Indus Basin Development Fund, comprising US$800 million funded by multilateral contributions and administered by the Bank, was established to help finance the water supply replacements works provided for under the Treaty. In 1968, the Tarbela Development Fund of US$1.2 billion was established, also with the Bank as Administrator, to help finance construction of one of the world's largest dams, at Tarbela on the Indus, designed to store 9.4 M ac-ft of water in kharif for release during subsequent periods of comparative water scarcity. WAPDA was designated in 1960 as the GOP's agency responsible for executing this unprecedented series of works.

2.14 The Indus Basin Development Fund (Supplemental) Agreement of 1964 provided for an extensive study to assist the GOP, by devising a planned program of development of the water, land and power resources of the Indus Basin in Pakistan. This Indus Special Study (ISS) was undertaken by the Bank, with the assistance of several firms of consultants 1/. The study included, as a first step, an appraisal of the Tarbela Dam Project. This part of the study was completed in 1965, while the proposals for an Action Program of large-scale irrigation and drainage development projects were completed and presented to GOP by the Bank in 1967.

G. Operation of the Indus Basin Project Works

2.15 Mangla Dam. The first significant reservoir storage to be provided for irrigation in Pakistan was Mangla Dam on the Jhelum River in 1967. Mangla was constructed to provide some regulating capacity towards the replacement of eastern river flows diverted by India under the Indus Waters Treaty, and to develop 600 MW of hydroelectric generating potential. Releases

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1/ Sir Alexander Gibb & Partners and Hunting Technical Services of London, England, and ILACO of Arnhem, the Netherlands (jointly forming the Irrigation and Agriculture Consultants Association, IACA); Charles T. Main of Boston, and Stone & Webster of New York, USA.

from Mangla reservoir's live storage of about 5.3 M ac-ft can more than double the mean, unregulated rabi flow in the Jhelum, previously about 4.7 M ac-ft. Effective use has been made of the storage to increase flows at the time of planting rabi wheat in Punjab between October and November. This regulation effect, with the additional water from a large increase in public and private tubewells, contributed significantly towards the expansion of the irrigated wheat acreage in Punjab from about 6.5 to 8.3 M ac between 1966 and 1970, whereas in Sind the wheat acreage has increased from 1.5 to 1.8 M ac. During the floods in 1973, storage capacity at Mangla reservoir reduced the flood discharge to 200,000 cusec, half the peak inflow above the dam; a similar effect was achieved during the 1975 floods.

2.16 Chasma Barrage. Relatively minor storage is now available at Chasma Barrage on the Indus, which was commissioned in 1971. Silting has already reduced the operational storage from 0.8 to 0.7 M ac-ft. After the allocation of 0.1 M ac-ft to the adjacent Paharpur Canal, the balance is to be equally shared, as an *ad hoc* arrangement, between Punjab, through the Chasma-Jhelum Link and Sind.

2.17 IBP Link Canals. The Rasul-Qadirabad-Balloki-Suleimanke (RQBS) and the Trimmu-Sidhnai-Mailsi-Bahawal (TSMB) Link systems connect the Jhelum River with the Sutlej, while the two separate link canals, the Chasma-Jhelum (CJ) and Taunsa-Panjnad (TP), connect the Indus with the Jhelum and Chenab (Map IBRD-11699). The RQBS system has a vital role in transferring water stored at Mangla to the areas previously fed by the eastern rivers, but it cannot receive supplies from the Indus. The TSMB system can be supplied by all the western rivers, including the Indus through the CJ Link.

2.18 All the IBP link canals have been successfully commissioned by WAPDA and operated by the Punjab Irrigation Department at, or near, their design capacities. Water transfers through the links have been higher in kharif than in rabi, except in the case of the RQ Link during rabi transfers from Mangla storage. Kharif withdrawals at the heads of canal commands have been at, or above, mean levels (which are below requirements in the Sutlej Valley) since the link systems have been operating, except for the very low inflow years of 1970 and 1971 on the Jhelum and Chenab. The Indus river commands, particularly in the Lower Indus region, have significantly increased their seasonal kharif and rabi withdrawals. On the other hand, canals taking off from the Jhelum and Chenab have had somewhat reduced rabi season withdrawals, although the timely nature of the deliveries from Mangla have contributed to increases in the average yield and total production of wheat in Punjab.

H. Tarbela Dam Project

2.19 Tarbela Dam. The live storage capacities of Mangla (5.3 M ac-ft) and Chasma (0.7 M ac-ft) will be augmented by Tarbela reservoir (9.4 M ac-ft) when the dam is commissioned, following the repair of the damage which occured in August 1974 in the course of impounding. The additional water supplies from Tarbela, which could be used for rabi or early or late kharif, may provide incremental diversions of between 5.5 and 7.0 M ac-ft at canal heads, above the mean present rabi diversions of about 28 M ac-ft. Actual incremental diversions due to Tarbela will depend on the scale of transmission losses and gains in the rivers, barrage ponds and link canals, as yet unknown in some cases.

2.20 Effective distribution and use of stored water from Tarbela is of critical importance to the orderly development of Pakistan's water resources. In the short term, Tarbela releases could most beneficially be used in existing canal commanded areas where no drainage problems exist, or where control of the water table and canal and watercourse remodeling have progressed sufficiently for additional surface water supplies to be introduced with impunity (see Annex 1, Table 2). In view of the unpredictable fluctuations in river flows, the most beneficial aspect of releases from Tarbela storage may prove to be the reduction of risk to farmers by the assurance of timely water supplies in critical sowing periods and by the prevention of disruptively low supplies in the rabi season. Farmers may then be more regularly inclined to use fertilizer and other additional farm inputs. This particularly applies in the major part of the irrigated area, which does not or cannot have the benefit of usable groundwater supplies from tubewells. Farmers on small and medium size holdings, largely bypassed by private tubewell development, would then have an opportunity to increase their production, thus providing a substantial contribution towards more equitable income distribution.

III. DEVELOPMENT SITUATIONS, MODES AND CONSTRAINTS

A. Development Situation

3.01 Crop production and farm productivity in the areas commanded by the Indus Basin canals vary considerably in relation to the existing standards of farms husbandry and environmental factors, including the microclimate and seasonal irrigation regimes, the cropping intensities established, water table levels, quality of groundwater, the soil fertility and, by no means least, the degree of salinization of surface soils. These situations and the various means of development to achieve improvements are described in the following paragraphs, together with the constraints which stand in the way of increased productivity and expeditious implementation of projects.

3.02 Most of the irrigation canals constructed in the early stages of development more than sixty years ago were designed to supply water from the rivers during both kharif and rabi (i.e., perennially), while others were allocated supplies only in kharif (i.e., non-perennially), and water rights were established accordingly. As the diversion of river flows for irrigation in rabi increased, water availability was reduced. Many of the canals constructed later were consequently designed to operate only in kharif (i.e. non-perennially). Nevertheless, canal command planners recognized that, to the extent possible, in that areas where fairly shallow, fresh groundwater was available, farmers would be able to supplement surface irrigation supplies by means of open wells or Persian wheels, so that canals were usually designed to be non-perennial. However, where the groundwater was saline or deep, and therefore unsuitable for domestic use or supplementary irrigation, water was distributed through perennial canals to support relatively low cropping intensities and provide drinking supplies throughout the year.

3.03 Fresh groundwater areas adjacent to the rivers, usually non-perennial commands, often have high water tables, particularly in kharif during periods of high river flow. The soils in some of these areas have been salinized as a result of underwatering, or because of capillary movement and evaporation of moisture from high water tables. In many cases, these areas are suitable for tubewell development which would provide supplementary irrigation supplies, water table control, and the means to remove excess salt from the soil. If these fresh groundwater areas were allocated additional surface supplies in rabi (i.e. were to be converted to perennial commands), the water table levels would rise and soil salinization would be increased unless drainage were provided by means of intensive tubewell development, or by horizontal drainage systems. The non-perennial areas at some distance from the rivers are often underlain by relatively deep saline groundwater, though soil salinity is frequently widespread in consequence of underwatering. If additional surface water supplies were provided to these commands through canal enlargement, sooner or later subsurface drainage would be required for watertable control and for removal of soil salts from the area.

3.04 In perennial commands in the northern zone which enjoy higher rainfall than the southern areas, the watertable tends to be lower than in the non-perennial areas. Lower irrigation requirements and seasonal water allocations per acre have, however, resulted in some gradual surface soil salinization due to the traditional tendency to underirrigate. Since the majority of the perennial areas are underlain by saline groundwater (particularly in Sind, Panjnad, the left bank of the Sutlej Valley, and in northern areas at a distance from the rivers), additional supplies during periods of high river flow could only be provided through enlarged canals. To prevent excessive rise of the saline watertables and increased salinization, subsurface drainage would have to be provided prior to canal remodeling, especially in the southern perennial commands where watertables are already high. In the remaining commands, subsurface drainage will inevitably be required in the medium or long term. Drainage would be either by tubewells, or by horizontal, buried tile drains, with provision for harmless disposal of the saline effluent in either case. Open surface drains are also needed in some of higher rainfall areas and those subject to flooding. These development situations are summarized and listed in Annex 1, Table 3.

B. Major Constraints

3.05 Inadequate canal distribution capacity. Additional and timely water supplies are essential factors for the increase of crop yields and irrigation intensities as well as for control of salinity. Most of the canal systems of the Indus Basin were designed for very low cropping intensities (commonly less than 85 percent), although year-round cropping is possible; intensities in excess of 150 percent are attained where water supplies permit, such as in the Vale of Peshawar. Owing to population pressures and increasing soil salinization, traditional low-intensity irrigated farming has had to be abandoned in many areas and some farmers have sought various means of increasing the depth of water applied to their reduced area under irrigation. Farmers have developed the traditional Persian wheel and new private tubewell supplies in fresh groundwater areas, though many have continued to practice underirrigation (water spreading), knowing that yields do not decrease in direct proportion to the dimunition of irrigation supplies. Water spreading is supposed to provide the maximum production per unit of water, particularly in a country where water is a scarcer resource than land, but it usually results in eventual salinization of the soil, with consequent adverse effects on crop yields. It is also widely practiced in the saline groundwater zones, where the main constraint to increased production is the relatively low distribution capacity of the existing canal systems. Enlargement and remodeling of canals are both needed for the distribution and utilization of additional irrigation and reclamation supplies available during periods of high river flow, when much water is wasted to the sea. The incremental supplies, available through remodeling, would permit increases in the area under irrigation and in cropping intensity during kharif, provide the water necessary for leaching of salts and soil reclamation, and tend to reduce the common malpractice of water spreading.

3.06 Other widespread constraints to effective and equitable distribution of the irrigation supplies available, at present and in future, include the poor condition of watercourses, unauthorized deliveries to some farms to the detriment of others, and the low standard of on-farm development, particularly the lack of fine land leveling on farmers' fields. The large seepage and escapage losses from canals and watercourses result in a significant reduction in the supply reaching farm holdings, particularly at the tail end of watercourses. The capacities of many watercourses will have to be suitably enlarged to take advantage of the increased supplies from the combined discharges from remodeled canals and tubewells. Since each farmer can handle a flow of about 1.5 cusecs, additional watercourses will have to be constructed where the increased discharge exceeds this flow. Both the construction and maintenance of watercourses is at present the cultivators' responsibility, and effective improvements will not only require expertise which is not available to the farmers, but also effective coordination of surveys, designs, realignment and supervision of construction as well as the organization of systematic maintenance. Nevertheless, since there are about 100,000 miles of irrigation watercourses in the Indus Basin, any significant, long-term improvement of watercourses and water distribution to farms would have a dramatic impact on water and soil management and on farm productivity. Efforts have already been made in various parts of the country to encourage farmers to improve their own water management, by way of realignment of farm channels and land shaping. A carefully planned, intensive program of irrigated farming development projects covering these improvement aspects could undoubtedly make a fundamental contribution towards increasing national agricultural production over the medium to long term. In the short term, such developments are more likely to be successful if implemented in areas where there is no pressing or impending drainage constraint, and where there are reasonable prospects for simultaneously and significantly improving water supplies. Such locations would require careful selection (see also Volumes I and III).

3.07 Lack of Drainage. Unless there are sufficient net outflows of subsurface water and salts from the crop root zones to maintain a satisfactory salt balance, increased water applications tend to depress crop production by gradually worsening the salinization of the soils, and in some instances cause waterlogging. This applies particularly to the areas underlain by water tables which are less than 5 ft from the surface for several months of the year; such a condition existed on about 2.6 M ac in Punjab in October 1972 and may have increased to 3.7 M ac after the 1973 flood. In Sind, more than 7 M ac have watertables less than 5 ft from the surface 1/. Some areas in NWFP are similarly affected. The prerequisite to improved conditions in these areas is appropriate subsurface drainage. Adequate drainage facilities are lacking except in some of the existing SCARP areas. With increasing surface water deliveries from Tarbela, the salinity problem could worsen significantly in poorly drained areas unless effective preventive or corrective measures are taken.

3.08 Of some 5 M ac underlain by shallow, saline water tables in the Indus Basin (excluding areas now considered unsuitable for irrigation development and those under rice cultivation), over 3 M ac may require special provisions for watertable control to permit satisfactory crop production and to prevent further soil salinization. The two alternative methods which can be used are:

(a) Horizontal drainage, by open channel or subsurface, horizontal tile drains; these have relatively high capital cost in areas of low soil permeability; and

(b) Vertical drainage by tubewells; these have relatively low capital cost but high operating and maintenance costs; they also have unsuitably high capital cost in aquifers with low groundwater transmissibility.

WAPDA and the Provincial Government of Punjab plan to use tubewell drainage in saline groundwater zones. Early consideration should be given to the possible alternative use of horizontal open or tile drainage in saline groundwater zones in Punjab and Sind in view of the lesser quantity of saline effluent which would have to be disposed of, and the recent increases in installation, operation and maintenance costs of tubewells. Pilot projects to examine the local feasibility of horizontal tile drainage, originally

1/ Lower Indus Report, 1966.

proposed for construction in 1969, are only now being prepared for implementation. The World Bank has recently appraised one such project in Khairpur District of Sind Province.

3.09 Large amounts of highly saline effluent from subsurface drainage systems cannot be disposed of satisfactorily until suitable outfall drainage works have been provided. For example, the Left Bank Outfall Drain, which can be the means of disposal of most of the effluent on the east bank of the Indus in Sind and which, in earlier planning proposals, was to have been started in 1968, should be given high priority in implementation. The associated projects for sub-catchment drainage should be coordinated with the arrangements for augmenting irrigation supplies by canal enlargement and remodeling. This applies especially in areas where drainage is a vital prerequisite to the application of additional surface water from Tarbela, if local farm productivity is expected to be continuously improved in consequence.

3.10 In over 7 M ac of the Basin where the water table is less than 10 ft deep and groundwater quality is considered satisfactory for irrigation, private tubewell development has been sufficiently intensive in some localized areas to have had some drainage effect, while the tubewell SCARPS have provided a large measure of control of the water table in about 3 M ac. In the prevailing situation of limited public resources, and taking into account the considerable potential for private tubewell development in fresh groundwater areas, there is a need to strike a judicious balance in priorities between (a) further public tubewell development in fresh groundwater areas, and (b) implementation of drainage projects (often including canal remodeling) in saline groundwater areas where deterioration of irrigated land is already occurring, or where lack of drainage would be a constraint on the use of additional surface water supplies from Tarbela. In view of resource constraints, private tubewell installation should be encouraged as much as possible, while public tubewells could be given a residual role in the foreseeable future in fresh groundwater areas. Within the available resources and implementation capacity, public tubewell construction could then be assigned to the drainage of appropriate saline groundwater areas.

3.11 The Need for Salinity Control. Although considerable areas scattered throughout the Indus Basin had been salinized by natural processes in past centuries, the situation was more or less in equilibrium before the inception of irrigation on a large scale. Following the development of extensive canal systems late in the 19th century, water seepage from canals and surface ponding has caused groundwater levels to rise about one to two feet per year. When the groundwater level rose to within about ten feet of the soil surface, upward movement of groundwater by capillarity became appreciable. Capillary rise and evaporation of the groundwater containing dissolved salts in varying proportions, with concomitant deposition of salts on or near the soil surface, has been an important cause of a rapid increase in the area of salt-affected soils. Widespread, traditional water spreading in kharif, underirrigation of crops in rabi, and the lack of soil leaching operations by farmers (due to ignorance, and a chronic deficiency of irrigation supplies) have probably been the main contributary factors in soil salinization. To a lesser extent, the use of poor quality tubewell water for irrigation has been an additional cause.

3.12 The extent and importance of soil salinization is indicated by the following. In the Punjab in 1972, approximately 3 M ac of the CCA of 19.7 M ac (15 percent) was reported to be severely salt-affected and another 3 M ac slightly to moderately salinized. In Sind in the mid-1960s, 4.9 M ac of the total CCA of 13.2 M ac was said to have been severely salt-affected. Recent estimates give the severely salinized area in Sind as over 6 M ac, or about 45 percent of the CCA. Severe salinization is reported to result in the abandonment of 10,000-20,000 ac each year in both Sind and Punjab. Slight to moderate soil salinity reportedly results in a loss of crop production in the Indus Plains of 10 percent or more of total output each year (see Technical Note No. 2).

3.13 The ameliorative measures necessary to control or reduce the salinity problem include construction of drainage facilities to lower high watertables, and the provision for the safe disposal of saline drainage effluent; fine land leveling of salt-affected farm lands and areas of salinized, culturable waste lands preparatory to applying reclamation waterings; cheap gypsum supplies where necessary to counteract alkalinity; additional, timely irrigation supplies for reclamation and routine leaching, and to encourage the elimination of water spreading; and better water management in the use of tubewell water supplies with chemical constituents of dubious quality. Requirements for these measures are largely indivisible; they are likely to be costly, and they require expertise which is presently scarce in Pakistan. The beneficial effects of reclamation and leaching are usually, however, largely obtained in one or two seasons, and provide significant crop yield increases. The difficulties of providing infrastructural inputs on a large scale should nevertheless not be underestimated, and the planning and organization requirements for successful implementation of counter-measures are considerable though by no means insuperable.

3.14 Rate of Groundwater Development. Early estimates of the pumping capacity that would be provided by the public tubewell SCARP and Irrigation Department programs by the time Tarbela Dam would be operational were 23 M ac-ft with 20,000 tubewells; these figures were revised in 1970 to 11,760 tubewells pumping 14.4 M ac-ft by 1975. However, in mid-1974, only about 7,600 SCARP tubewells and about 1,000 Irrigation Department wells were operational, with an annual pumpage of approximately 7 M ac-ft. Private tubewell development on the other hand has exceeded earlier expectations, as over 100,000 wells have been installed, with an estimated pumpage of about 17 M ac-ft per year. The installation rate of private tubewells has, however, slowed down from over 10,000 to 4,000 or less per year, partly because of the increased cost of diesel fuel (two-thirds of the private wells are diesel powered). Further growth could be obtained by the promotion and manufacture of smaller capacity (1/2 or 1/4 cusec) tubewells, better suited to the very small farmer; the installation of inexpensive shunt capacitors on all existing electric tubewell motors to reduce the reactive KVA, and thus increase the load capacity of the distribution system; and through increasing the density of power distribution lines in fresh groundwater areas.

3.15 The two main impediments to implementation of existing public tubewell SCARPS have been lack of finance and delays in electrification, also largely attributable to financial constraints. Difficulties also arose in the operation of tubewell SCARPS due to water distribution problems caused by the inadequacy of connecting channels from the large (3 to 4 cusecs) tubewells to the watercourses which they were supposed to serve; lack of capacity of the watercourses and farmers' field channels to permit delivery of combined canal and tubewell supplies (see para 3.06); deficiencies in tubewell operating and maintenance arrangements; and lack of adequate revenue collections to finance the cost of operations. Other problems include the reducti in pumping capacity of some of the early SCARP tubewells due to deterioration of a significant number of the screens or possibly the surrounding gravel pack, and soil deterioration in some areas as a result of improper use of poor quality groundwater. The amount of salinized land actually reclaimed or improved in the SCARP areas is not known, but is believed to be disappointingly small. Some of these deficiencies would be surmountable through Provincial or Federal projects, specifically designed to eliminate such constraints as inadequate distribution capacities of tubewell connecting channels and watercourses, deficient construction standards for small canals, inadequately staffed and equipped tubewell maintenance organizations, and insufficient drilling capability for replacement of deteriorated tubewells.

3.16 The SCARP program has also been delayed recently due to differences in opinions on the design of wells and on suitable criteria for the quality of usable groundwater. These planning issues could have an important effect on the potential quantity of groundwater available for irrigation as well as the area irrigable by tubewells. They will need to be resolved before a significant number of projects can be satisfactorily prepared for consideration by the World Bank Group. A review of existing data and field situations by a carefully selected team of independent, fully qualified and experienced experts would provide a rational basis for closely monitored trials of alternative tubewell types and water application techniques, designed and implemented as an experimental project with the minimum possible delay in each Province (see Technical Notes Nos. 2 and 3).

3.17 Implementation Capacity. The projects to be implemented in the next five-year period are more diversified and extensive than in previous sector development programs and include surface and subsurface drainage, canal remodeling, flood protection, as well as tubewell projects. There will be considerably increased requirements for planning and project preparation capacities to handle the expanded work load; the available capacity of experienced professional staff is inadequate, and is virtually certain to be a constraint on progress. The need for expert foreign assistance, especially from individuals, consulting firms and agencies having the necessary experience of local conditions and planning requirements, is recognized by GOP and the Provincial Governments. However, in view of the plethora of opinions held on the extent of previous achievements in planning Pakistan's irrigated agricultural development, considerable care would have to be taken in providing for such assistance whenever it is requested by GOP.

3.18 The implementation of the engineering aspects of most irrigation and drainage projects is the responsibility of WAPDA, which has been divided into two regional offices, covering most of Baluchistan and Sind Provinces from Hyderabad, and NWFP and Punjab Province from Lahore. WAPDA has usually engaged consultants for detailed preparation of projects and for supervision of construction. Local Pakistani consulting firms have already undertaken heavy workloads, with variable results; there are indications that some of their survey, design and preparation work for irrigation farming development projects is progressing well, although as yet on a limited scale. The Bank is in a position to encourage the appropriate training and extension of experience of the many competent professionals employed by WAPDA and local consultants so as to increase their effectiveness. Opportunities to provide such training through EDI courses, and for exposure to project implementation in other Bank member countries, should be promoted in Pakistan whenever possible, with provision for close supervision and evaluation of trainees.

3.19 The construction capacity of the local civil engineering contracting industry has not expanded significantly during the past decade, and has remained largely labor-intensive. There is ample labor and animal draft power available for small-scale work throughout most of the year, albeit on a seasonal basis. Several types of construction work are traditionally carried out largely labor-intensively, including the remodelling of barrages and canal structures, canal enlargement, stone protection of flood embankments (bunds), watercourse and field channel construction, canal, drain and road maintenance. For larger-scale works, local contractors who would prefer to mechanize are constrained by the difficulties and cost of obtaining imported equipment and spare parts, as well as the cost of fuel. There is no shortage of trained and expdrienced equipment operators and supervisor as a result of the Indus Basin and Tarbela Projects, though many have le.t the country. As a matter of policy, and to use the signficant quantities of supplus equipment from these projects which are vested with WAPDA, including machinery for link canals, dams, SCARP tubewells, and power transmission lines, the Federal Government has recently set up separate autonomous contracting companies in specialist construction fields, such as heavy civil engineering, tubewell installation, and electrical transmission. These enterprises are now in the early stages of mechanization and development. Their capacities for carrying out large-scale irrigation canal enlargement, subsurface tile drainage or tubewell installation and energezing works are as yet untested. An evaluation of the construction industry, possibly by the Bank after discussion with GOP, would contribute significantly to the planning process. It would also provide an indication of the requirement for foreign contracting involvement, and foreign exchange, towards meeting project implementation targets.

3.20 Agricultural Supporting Services. There is much evidence from areas at present reasonably well supplied with water, and which are not in immediate need of drainage and salinity control measures, that agricultural production is not increasing quickly enough, due to inadequate supporting services. Improved arrangements for production and dissemination of modern inputs as well as strengthened credit, research, extension and marketing services remain important development objectives for Pakistan as discussed in more detail in Volumes I and III-V.

3.21 The construction and regular maintenance of watercourses and field channels by farmers has traditionally (and by force of necessity during periods of rapid expansion of irrigation development), been largely left to cultivators to carry as best they can. The gradual improvement of farm productivity will be increasingly dependent on an efficient supply of water, and there will be a pressing need to create effective local organizations for the proper operation and maintenance of watercourses by those concerned. This could probably be most usefully encouraged at chak or village level, possibly as part of a provincial or national movement for such improvement, with the added incentive of ensuring more equitable distribution of irrigation water. The Farmers' Associations which are being formed in the Provinces may be able to give an appropriate lead in establishing such recognized chak farmers' organizations. These, or some other suitable arrangement would gradually have to replace the existing weak arrangement whereby the irrigation "patwaris" and the executive engineers of the Provincial Irrigation Departments devise and supposedly supervise the allocation of "turns" in which individual farmers are expected to receive water during the periods when each watercourse is flowing (see Volume III).

C. Development Modes

3.22 Annex 1, Table 2 presents a schematic listing of the development situations in the canal commands, the physical deficiencies to be overcome by institutional investment, since they are largely beyond the capacity of farmers (particularly the smaller farmers) to resolve; and the various modes of progressive infrastructural development that are possible. The terrain and the aquifer conditions are, however, not uniform within a whole drainage catchment or canal command, and the proposed solution may have to be varied over relatively short distances.

3.23 Eight major development situations can be identified, and the two main, large-scale infrastructural deficiencies are the lack of drainage (with the need for reclamation of saline lands), and the shortage of timely and reliable water supplies (with the need for increased canal distribution capability in periods of high river flow). The table indicates possible development modes for each situation. The development modes in the various situations may, however, be interrelated; for instance, a solution for drainage (including effluent disposal) in one area may influence the situation and solutions in other areas, particularly downstream. Moreover, the solutions may be interrelated in terms of phasing: a temporary solution for a water shortage situation by means of additional canal supplies, particularly while water from storage at Tarbela is temporarily not fully used, may have to be revised in the longer term, and the source changed to more expensive groundwater. The two major problems to be resolved are also interrelated in some of the development situations. The resolution of the drainage problem in a fresh groundwater area may provide additional water for irrigation further downstream in the system whilst, in saline zones, soil reclamation would be restricted unless additional water for leaching were to be provided.

3.24 Thus a systematic project planning approach, taking full account of interdependence within and between canal commands, will be required for the short- and medium-term national development program. Planning must start from the individual canal command or hydrological unit situations. However, the solutions derived will require coordination at the local, Provincial and Federal levels to fit them into an integrated national system. Tentative suggestions for alternative distributions from Mangla and Tarbela storage releases are implicit in Annex 1, Table No. 2, derived from the technical possibilities of water transfer, as well as assumptions regarding the groundwater quality and watertable state in the canal command components listed. The groundwater status in each area is variable however, and will probably deteriorate significantly wherever drainage remains uncontrolled (see Technical Note No. 1)

3.25 The Irrigation and Drainage Review mission considered, however, that there are several other relevant modes of development which could increase agricultural productivity considerably in Pakistan. They would appropriately be given more detailed consideration in the review of crop variety adaption potential, research programs and other activities recommended in Volume I. In brief, these modes include the following:

(a) the large-scale introduction of improved varieties of such cereals as salt-tolerant durum wheat and barley, kharif-grown grain sorghum and rice, specially developed elsewhere to meet adverse saline soil and scarce water conditions similar to those present throughout most of the Indus plains, and with considerable export potential;

(b) the radical improvement of agricultural extension service operations throughout the irrigated areas of the Provinces, to effect major, sustained improvements in their effectiveness;

(c) the expansion of lending for agriculture by the commercial banks as well as the ADBP, to enable any credit-worthy farmers to finance their short, medium and long-term needs, particularly for on-farm, minor infrastructural development, without further straining governmental budgetary allocations for projects; and

(d) the nation-wide encouragement of equitable distribution of irrigation water to every farm holding on each watercourse.

3.26 The permanent removal of harmful salts from the surface soils in the cultivated areas of the Indus plains will inevitably extend over a decade or more. It will therefore be advisable, and even necessary, to plan to meet a latent, long-term demand for higher-yielding varieties of crops which have been bred to withstand saline soil conditions. The persistent local preference for staple durum wheat, with its relatively high gluten content and its suitability for chipatti-making, is well known; durum varieties have been developed which not oonly have comparatively good yield potential but are also tolerant of high salt contents of soils and water. Although barley is not at present widely grown for consumption in Pakistan, it is by nature salt-tolerant and might be grown for export. Relatively high-yielding varieties have been developed in Mexico and the USA. Given marketing incentives, production of these or local strains of barley might be considerably increased by farmers on large areas of the Indus plains in which cropping will otherwise be constrained by salinity for many years to come. Grain sorghum is another crop with considerable potential which, though not popular in Pakistan at present, would be emminently suitable for introduction as a significant component in kharif cropping patterns (see Volume I). Also cotton is highly salt-tolerant and warrants further encouragement for this reason, although it already is a major export crop.

IV. TOWARDS A REVISED ACTION PROGRAM

A. The Need for a Program

4.01 The completion of Tarbela, with an initial live storage of 9.4 M ac-ft, will increase the water supplies available for diversion at main canal heads in the Basin by between 13 and 23 percent, depending on whether they are used in rabi alone or also in other periods of water scarcity. To ensure effective use of available irrigation supplies, the Indus Special Study (ISS), carried out by the Bank between 1964 and 1966 (see paragraph 2.14), recommended an Action Program of projects for implementation during the period 1967-75. The ISS Action Program was geared to effective distribution and use of available irrigation water, expeditious soil reclamation and control of waterlogging and salinity through public and private groundwater development, surface drainage schemes, as well as improved and intensified agriculture supporting services.

4.02 Both the GOP and the Bank had recognized that the ISS Action Program would seriously strain budgetary, technical and administrative capacities and that its successful completion would require a national commitment of the highest order. The GOP's recognition of the need for rapid action was, nevertheless, instanced by its publication, "Proposal for an Accelerated Programme of Waterlogging and Salinity Control in Pakistan," published by the Planning Commission (Water Resources Section) in September, 1973. However, between 1965 and 1974 only one third, cost-wise, of the investments recommended by ISS had been implemented. On the whole, the Program is about five years or more behind the schedule originally proposed (see Annex 2). This is partly because technical and administrative difficulties affecting the implementation of public tubewell projects had been considerably underrated, and because financial stringency (resulting from political unrest and hostilities) interferred with orderly progress of the Program. The short-term success of the new HYV wheat technology 1/ induced complacency and led to a slow-down in water control investments. Volume III probes further into the evolution of agriculture and water policies in Pakistan.

4.03 The economic, technological and political fractors influencing the framework for water planning have changed radically since the ISS Action Program was devised some ten years ago. These factors include:

(a) the effects of new crop varieties (HYV of rice and wheat), as well as changed world market prospects, which must be taken into consideration;

(b) tubewell design criteria as well as the desirable balance between public and private groundwater development, which need review;

(c) the new energy cost situation may have madehorizontal drainage relatively more attractive than vertical drainage by tubewells, given sharply rising pumping costs;

(d) the 1973 and 1975 floods have brought the importance of flood control and warning systems into sharper focus;

(e) the Government now gives greater weight to regional balance factors and to income distribution objectives;

(f) the forthcoming availability of stored water from the Tarbela Project, in advance of the necessary complementary drainage infrastructure, is itself a major new element in planning for the sector;

(g) basic data has become outdated regarding waterlogging, soil salinity, farming systems, yields, input needs, water requirements, as well as cost and benefits; they need to be reviewed and updated, to enable Provincial water distribution and Federal investment decisions to be made;

1/ High-yielding varieties of Maxi-Pak wheat were introduced on a large scale in 1966/67.

(h) the imperative need for improving water management, in particular, on water courses and farms as well as that of improving cultural practices in irrigated agriculture in order to realize the potential of drainage, waterlogging and salinity control and irrigation projects, is now appreciated at the highest levels in the Government and has resulted in a broadened, fully integrated agriculture sector strategy as outlined in Volume I.

4.04 Without an effectively planned, comprehensive development program for irrigated agriculture, full benefits may not be derived for some time from the massive investments already made in the Indus Basin Works (US$1.0 billion equivalent) and the Tarbela Project (US$1.2 billion equivalent). The ISS Action Program proposals were modified by Bank missions in 1968 and 1970, and they again need to be revised, taking full account of these new circumstances. At the Bank's suggestion, the GOP has recently begun the preparation of a revised Action Program and an updated national investment schedule for irrigated farming development and land reclamation in the Indus Basin, with financial assistance from UNDP.

B. New Planning Activities

4.05 The new planning program is being carried out as a UNDP Project and has the following objectives:

(a) Updating basic data relevant to sound agriculture and water planning in the Indus Basin;

(b) Reviewing key technical issues affecting design and implementation of irrigation and drainage projects in the Basin;

(c) Reviewing and updating GOP's development program for the planning, preparation and implementation of surface storage and related hydro-electric generation, drainage, reclamation and flood protection schemes during the next fifteen years, irrigation, responsive to the economic and social objectives of the Government and consistent with likely funding and implementation constraints;

(d) Obtaining essential direction from a new Federal Board for Irrigated Agriculture Planning and Development, especially as regards basic policy, production targets, socio-economic priorities and prospective financial allocations for the sector, consistent with new agriculture sector strategies, policies and programs resulting from mutual understandings between GOP and the World Bank;

(e) Estimating the probable range of incremental output of agricultural products arising from the revised Action Program, the phasing of required investments, and the staffing and training requirements for implementation of the Program; and

(f) Facilitating projections of surface water distribution and use.

4.06 The revision of the Action Program is viewed as a continuous land and water planning process, with appropriate updating from information and new data as they become available. Responsibility for this planning operation falls on the GOP's Ministry of Fuel, Power and Natural Resources, assisted by the Federal and Provincial Governments' development and technical planning agencies. The UNDP Indus Basin Planning Project will assist this process over a period of three years. The Bank, as Executing Agency on behalf of UNDP, has engaged Harza Engineering International as its consultants for the Project, to provide additional support and guidance to WAPDA which has been designated by GOP to carry out the work (see Annex 4).

4.07 It will be necessary to provide for complete coordination of the Indus Basin Planning Project with the future integrated planning of the agriculture, power and other related sectors. To achieve the required full coordination and support for the project, a National Board for Irrigated Agriculture Planning and Development will be established with representatives from all Ministries concerned, the Provinces, and the private sector. The Board is expected to have powers of direction of staff, and for obtaining decisions on matters of planning policy from the Ministries concerned (Annex 4). For coordination at provincial level, comparable provincial boards are proposed (see para xx of Volume III). Provincial Planning, Agriculture and Irrigation Departments will be called upon to plan for improvement of water management on watercourses and farms, and to strengthen agricultural extension and underlying research for improved cultural practices. The FAO/IBRD Cooperative Program has already started a project preparation effort towards such objectives, to generate farmer demand for innovation, and to ensure a basis for decisions involving Government.

C. Water Distribution Patterns

4.08 Optimum use of additional Tarbela water supplies from the national standpoint will undoubtedly call for flexibility in water distribution over time, to take account of the need to develop complementary measures for effective utilization of surface water. In the long run, a significant part of the stored water might well be used in areas underlain by saline groundwater, since farmers in such areas have no alternative irrigation supply sources. To the extent possible, water distribution within the Provinces should be based on the potential within each water-short canal command for beneficial absorption of additional surface water in periods of scarcity. As discussed in Section III, this potential is determined not only by the present groundwater status but also by the natural or installed drainage capability available to control future water levels (Annex 1, Table 3). This means that an optimum pattern for long-term water distribution is dependent on the design of a feasibility program of complementary infrastructure investment projects. Conversely, regional programs for water control investments are intimately linked to decisions regarding stored water distribution, which are themselves bound to reflect political imperatives (see Technical Note No. 1).

D. Special Studies

4.09 Criteria for Usable Groundwater in Development Planning. During the 1960s, intensive investigations by WAPDA and its foreign consultants led to the adoption of certain water quality standards for groundwater use, and various design criteria for tubewells and tubewell fields. The water quality standards were established primarily for regional planning purposes rather than project preparation. The public tubewell SCARPs carried out to date in Punjab have adhered to these previously established standards. By the late 1960s, technical difficulties were encountered in the SCARPs which reduced their effectiveness because of some deterioration in soil fertility in limited areas. Results observed in these SCARP areas have since led to these standards and criteria being questioned by the Government of Punjab, principally with respect to their appropriateness under local conditions. WAPDA's reaction to these problems eventually resulted in the adoption in 1973 of a revised set of water quality standards, which impose much more restrictive criteria, and would result in a very considerable reduction in the groundwater resource potential available for irrigation. The Federal Government has indicated to the Bank that it does not intend to apply the water quality standards rigidly, and has requested assistance in the form of technical experts towards formulating more suitable criteria. A special study by highly qualified advisers will be undertaken by the Bank's consultants and WAPDA, to provide basic guidelines for the Planning Project, and which would be applicable to the varying soil and groundwater conditions encountered in the Indus Basin (Annex 4).

4.10 At the Provincial Government level, suitable solutions to the water quality problems will be sought through application of these guidelines and standards, with allowances made for the improvement in on-farm soil and water management attainable with land leveling and better education of farmers, and the proper consideration has been given to the variability of local soil characteristics, the availability and use of gypsum, the provision of saline water dilution facilities, the appropriate location of tubewells, and the potential for increasing surface water supplies for reclamation and leaching of saline soils.

4.11 Criteria for design of SCARP tubewells. Revised criteria for design of shallow tubewells currently used for feasibility studies could not adequately provide for the alleviation of shortages in surface supplies in years of low river flows, a concept fundamental to the integrated development of surface and groundwater. These design criteria will be thoroughly reviewed through a special study by the Bank's consultants and WAPDA. As in the case of the water quality criteria study, the resulting guidelines will need to be applied in specific cases, taking full account of the particular ccondi-tions of each project (Annex 4).

V. FUTURE PROJECTS FOR EXTERNAL FINANCING

5.01 In most of the Indus plains, significant increases in production of existing crop varieties will be quite difficult to achieve without the prerequisities of reasonably satisfactory drainage conditions and timely, assured additional irrigation water supplies at the farm level. The latter will be obtained not only through tubewells and appropriate reservoir storage releases during water-short periods, but also by the enlargement of distribution canals, rehabilitation of watercourses and provision of appropriate on-farm field channels, to enable the additional diversion and use of water from the rivers during the periods of high flow. Sustained advances in the productivity of existing or improved crop varieties will also depend on the introduction of better on-farm irrigation practices, certified seed, more efficient crop husbandry and adequate plant protection (see Volumes I and III). Trained reclamation teams will be required to ensure that appropriate standards of construction are adopted and implemented for watercourse reconstruction and for the leveling and treatment of severely salinized lands. Intensified agricultural advisory services will need to ensure that proper emphasis is given by farmers to efficient irrigation practices and routine control of soil salts through leaching, and improved agricultural support facilities will have to include facilities for better distribution of seed and storage of harvested crops (see Volumes I and V).

5.02 The Federal and Provincial Governments will need to make the largest possible budgetary outlays, consistent with overall agriculture sector priorities (Volume I), to effect essential improvements in public irrigation and drainage infrastructure, construction, operation, maintenance and staffing. This will require projects providing for saline drainage effluent disposal; soil reclamation facilities; canal enlargement on a large scale; means of using drainage return flow; water saving by lining of canals; general improvement of canal control and water distribution structures, as well as supporting infrastructure such as improved farm-to-market roads. In view of the large number of infrastructure projects which have already been identified in these fields and the number of technical and planning issues to be resolved, it would be appropriate for the World Bank Group to consider providing financial assistance for several pioneering projects, designed to introduce and adapt well-tried techniques which are new to Pakistan, as the most effective means of contributing to the GOP's program of irrigation and drainage infrastructure projects (see para 4.07).

5.03 Because of the exceptional size of the Action Program, problems of choice of appropriate projects are certain to occur. It is imperative for water resources development projects chosen for implementation in the next 5-10 years to make a substantial contribution to agriculture production growth. This emphasizes the importance of quick-yielding projects. Selection will probably be also influenced by such technical factors as pioneering characteristics (possibly including new cost-reducing technology such as mechanized drainlaying, tubewells capable of pumping fresh and saline groundwater simultaneously, saline drainage effluent evaporation, inexpensive prefabricated lining for small channels and the distribution of low-cost liquid fertilizer); and the importance of phasing with other inter-related projects. Project selection will be influenced by other factors as well, such as the proportion of foreign exchange requirements, particularly as regards specialist overseas contractors, equipment and expertise; their employment effect; and their sheer size, cost and complexity, as in the case of the LBOD (see paragraph 4.24). Further factors which will affect project selection include matters such as the status of preparation to acceptable standards, prior decisions or agreements regarding water distribution and availability, including areas which do not receive their authorized water supply such as the lower reaches of watercourses (commonly inadequately maintained for equitable water distribution), and last, but not least, their impact on rural poverty, particularly in areas menanced by declining productivity due to increasing soil salinity.

5.04 <u>Constraints on Selection</u>. At present, unresolved technical issues considerably restrict the selection of projects which would be suitable for external financing in the short-term. The rapid appraisal by the Bank of any one of some twelve tubewell SCARP projects, all of which WAPDA wishes to start within the next three years, would be dependent on satisfactory project preparation. This would include the resolution of the technical issues concerning soil and groundwater quality, tubewell design and related matters, described in paragraphs 4.09 through 4.11, an appropriate redifinition of the role of private tubewells, and the formulation of realistic improvement programs for water management on watercourses and farms as well as cultural practices. Most canal remodeling projects are complex and difficult to prepare; only one, Khairpur III, is likely to be in a sufficiently advanced state of preparation to appraise within the next two years or more. All of them will depend on firm decisions by Provincial Governments regarding additional water distribution to the canal commands concerned. Projects for the extension of irrigation areas will likewise be subject to Provincial Government decisions on water distribution and use, and their size as well as their location will also be determined by the priority accorded to other needs for available water. These include the considerable quantities of water required for raising present cropping intensities, reducing soil salinization in existing areas, and for reclamation of culturable, saline lands already commanded by canals.

5.05 On the other hand, projects involving horizontal drainage are unlikely to be impeded to the same extent by technical or other planning constraints. An especially difficult case, however, is the very large Indus Left Bank Outfall Drain (LBOD) Project, which is an essential component of the regional plan for reclamation of about 4 million acres in Sind, and is considered to be a high priority project. It is directly linked to the execution of specific sub-catchment drainage projects which are, in turn, linked to canal remodeling and other storage schemes for provision of additional water supplies, without which the drainage projects may not be viable. These surface water schemes are themselves dependent on the resolution of technical issues arising out of the development proposals for the Indus Left Bank in Sind. Until the regional plan is advanced to a stage at which all its components can be approved in principle for financing by the Federal Government, adequate implementation of the LBOD project will be severely handicapped.

5.06 To enhance the benefits obtained, irrigation development projects are no longer comprised of the major construction works alone. They now usually include provision for elements which will accelerate the build-up of project benefits, and hence will assist in increasing the probability that the project will be successful. This concept requires that the design of each project should be sufficiently comprehensive to ensure rapid, positive changes in the confidence and cooperation of farmers with the agencies responsible for project implementation, as well as to achieve significant, early production gains from the project.

5.07 Consequently, prior to appraising selected projects in Pakistan the main technical concerns of the Bank would be that accurate and up-to-date data had been assembled on the status of all relevant parameters of irrigated agriculture in the project area, including the social, economic and institutional aspects; that the outstanding technological issues had been resolved (see paragraphs 4.18 to 4.20); and that the feasible alternative means of implementation had been adequately considered. In addition, during the design and preparation stages of each irrigated agriculture project in the Indus Basin for which GOP intends to request Bank assistance, provision should be made for such components as the following, with assistance from foreign experts where necessary:-

(a) effective management and staff training for intensified, highly-geared Provincial agricultural extension services, and arrangements for the selection and sustained motivation of project staff (see para 4.06 and Volume I, para xii);

(b) funding arrangements for production and development credit on terms suitable for small farmers, enabling essential on-farm improvements such as land levelling to be carried out by the beneficiaries (see Volume I, para xiii);

(c) thorough training and deployment of land levelling and soil reclamation supervisory teams, including agricultural engineers and soils specialists;

(d) sufficient monitoring of the project impact, with appropriate analysis, to identify any need for changes in the thrust of components; and

(e) air survey and soil salinity and groundwater mapping, with topographical survey for planning land leveling, watercourse improvements and drainage works.

The agency responsible for preparing and implementing most irrigation and drainage projects in Pakistan is WAPDA (see para 4.07), and some strengthening of their agricultural and economic staff components will be necessary in order to meet these requirements. Close coordination between WAPDA and the Provincial agricultural agencies will be especially important.

5.08 During 1976 through 1978, projects to be considered by the Bank will be selected from those accorded the highest priority within the agriculture sector by GOP. They would be designed to include auxilliary components to assist with the preparation of further high priority projects to the required standard, indicated above. The Bank has informed GOP that the initial selection will include one tubewell SCARP as well as Khairpur II, a "pathfinder" tile drainage project which also contains essential on-farm development elements. The projects to be identified and appraised after 1978 would be selected from the revised Action Program arising out of the UNDP Indus Basin Planning Project, which will reflect sector-wide priorities in its recommendations.

5.09 Advance farming development. On-farm development projects, especially the intensified agricultural extension component, should be started in advance of implementation of the major Indus Basin irrigation and drainage projects. This work could be carried out as part of other projects covering agriculture and rural development, for which financial assistance may be provided by the World Bank Group. This spearhead approach would however be applicable mainly in those Provincial administrative districts where the physical conditions of drainage and soil salinity are not so adverse as to prevent significant increases in productivity, through the systematic, large-scale improvement of crop husbandry, pest control and fertilizer practices. These advance activities can be introduced through carefully planned irrigated farming development projects referred to in Volumes I and III.

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW
VOLUME II : IRRIGATION AND DRAINAGE

INDUS BASIN CANAL COMMANDS

Serial No.	Region & and Canal Command	Culturable Commanded Area, M ac: Command	Region	Seasonal Canal Supply	River Source	Diversion Point
	Vale of Peshawar					
(1)	Upper Swat	0.277		Perennial	Swat	AmAndara
(2)	Lower Swat, Doaba and Sholgara	0.169		Perennial	Swat	Munda
(3)	Kabul River, Jui Sheikh and Inundation	0.123		Perennial	Kabul	Warsak, below
(4)	Warsak High Level, Right and Left Bank	0.119		Perennial	Kabul	Warsak, above
	Regional sub-total	0.688	0.688			
	Thal Doab and Middle Indus Right Bank					
(5)	Thal	1.641		Perennial	Indus	Kalabagh
(6)	Paharpur	0.105		Non-perennial	Indus	Chasma
(7)	Rangpur	0.343		Non-perennial	Chenab/Jhelum/ Indus	Trimmu, right bank
(8)	Muzaffargarh	0.656		Non-perennial	Indus	Taunsa, left bank
(9)	D.G. Khan	0.872		Non-perennial	Indus	Taunsa, right bank
	Regional sub-total	3.617	3.617			
	Chaj Doab					
(10)	Upper Jhelum	0.376 0.167 0.543		Perennial Non-perennial	Jhelum	Mangla
(11)	Lower Jhelum	1.285 0.215 1.500		Perennial Non-perennial	Jhelum	Rasul
	Regional sub-total	2.043	2.043			
	Rechna Doab					
(12)	Marala-Ravi Link	0.105		Non-perennial	Chenab	Marala
(13)	Upper Chenab	0.613 0.832 1.445		Perennial Non-perennial	Chenab	Marala
(14)	Lower Chenab	2.833 0.148 2.981		Perennial Non-perennial	Chenab/Jhelum	Khanki/Qadirabad/Rasul
(15)	Haveli	0.063 0.080 0.143		Perennial Non-perennial	Chenab/Jhelum/ Indus	Trimmu, left bank/Chasma
	Regional sub-total	4.674	4.674			
	Bari Doab					
(16)	Ravi Syphon-Dipalpur Link	0.595		Perennial	Chenab	Marala
(17)	Dipalpur above BS Link	0.372		Non-perennial	Chenab	Marala
(18)	Dipalur below BS Link	0.611		Non-perennial	(Ravi) 1/ Chenab/ Jhelum	Balloki
(19)	Lower Bari Doab	1.527 0.048 1.575 2/		Perennial Non-perennial	(Ravi)/Chenab/ Jhelum	Balloki
(20)	Pakpattan above TSMB Link	0.607 0.332		Perennial Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum	Suleimanke, right bank
(21)	Mailsi above TSMB Link	0.015		Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum	Suleimanke, right bank
(22)	Pakpattan below TSMB Link	0.313 0.006 0.319		Perennial Non-perennial	(Ravi)/Chenab/ Jhelum/Indus	Sidhnai
(23)	Mailsi below TSMB Link	0.677		Non-perennial	(Ravi)/Chenab/ Jhelum/Indus	Sidhnai
(24)	Sidhnai	0.493 0.261 0.754		Perennial Non-perennial	(Ravi)/Chenab/ Jhelum/Indus	Sidhnai
	Regional sub-total	5.857	5.857 2/			
	Regional sub-totals carried forward		16.879			

Serial No.	Region, and Canal Command	Culturable Commanded Area, M ac Command	Region	Canal Supply	River Source	Diversion Point
	Regional Subtotals brought forward		16.879			
	Bahawalpur Plain 3/					
(25)	Fordwah	0.062 0.365 0.427		Perennial Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum	Suleimanke left bank
(26)	Eastern Sadiqia	0.913 0.022 0.935		Perennial Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum	Suleimanke, left bank
(27)	Qaim	0.042		Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum	Islam
(28)	Bahawal above TSMB Link	0.051		Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum	Islam
(29)	Bahawal below TSMB Link	0.275 0.321 0.596		Perennial Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum/Indus	Sidhnai
(30)	Abbasia	0.067 0.042 0.109		Perennial Non-perennial	(Sutlej)/(Ravi)/ Chenab/Jhelum/ Indus	Panjnad
(31)	Panjnad	0.446 0.900 1.346		Perennial Non-perennial	(Sutlej)/ (Ravi)/ Chenab/Jhelum/Indus	Panjnad
	Regional sub-total	3.506	3.506			
	Lower Indus					
(32)	Begari Sind	0.703		Non-perennial	Indus	Gudu, right bank
(33)	Desert and Pat	0.382		Non-perennial	Indus	Gudu, right bank
(34)	Ghotki	0.513		Non-perennial	Indus	Gudu, left bank
(35)	North West	0.588		Perennial	Indus	Sukkur, right bank
(36)	Rice	0.372		Non-perennial	Indus	Sukkur, right bank
(37)	Dadu	0.394		Perennial	Indus	Sukkur, right bank
(38)	Eastern Nara (incl. Nara pumps)	1.453 0.190 1.643		Perennial Non-perennial	Indus	Sukkur, left bank
(39)	Khairpur East	0.330		Perennial	Indus	Sukkur, left bank
(40)	Rohri	2.480		Perennial	Indus	Sukkur, left bank
(41)	Khairpur West	0.252		Perennial	Indus	Sukkur, left bank
(42)	Kalri Baghar	0.115 0.159 0.274		Perennial Non-perennial	Indus	Kotri, right bank
(43)	Pinyari & Fulèli	0.897		Non-perennial	Indus	Kotri, left bank
(44)	Gaja	0.062		Perennial	Indus	Kotri, left bank
(45)	Tando Bago	0.090		Perennial	Indus	Kotri, left bank
	Regional sub-total	8.980	8.980			
	Total culturable commanded area (CCA) for development		29.365			
	CCA provisionally excluded from development of Lower Indus Region		4.224			
	Total CCA		33.6	million acres		

1/ Under the terms of the Indus Waters Treaty, Sutlej and Ravi waters are available for unrestrictive use by India, except as expressly provided in the Treaty. In flood seasons, however, some flow into Pakistan can be expected.

2. About 31,000 ac of Lower Bari Doab Canal command are in Rechna Doab. Actual Rechna and Bari Doab regional CCA's are therefore 4.705 and 5.826 M ac respectively..

3/ Comprises Sutlej left bank below Suleimanke and Panjnad left bank.

PAKISTAN

ANNEX 1
Table 2

SPECIAL AGRICULTURE SECTOR REVIEW
VOLUME II : IRRIGATION AND DRAINAGE

TENTATIVE LIST OF CANAL COMMANDS CAPABLE OF ABSORBING ADDITIONAL SUPPLIES IN SCARCE WATER PERIODS FROM MANGLA AND TARBELA IN THE SHORT TERM 1/

Canal Command	CA 000 ac	Present Supply 2/	Development Status 3/	Groundwater Status 4/	Diversion Barrage(s)	Upstream Resevoir(s)
Thal	641	Peren.	ADC tubewells (part); low cropping intensity	Fresh; low watertable	Kalabagh	Tarbela
Rangpur	343	Non-peren.	Low cropping int. part in SCARP III	60% fresh; low watertable	Trimmu, Chasma	Tarbela, Mangla
Muzzaffargarh	656	Non-peren. (part)	SCARP III tubewells completed	30% saline; controlled watertable	Taunsa	Tarbela
Dipalpur below BS Link	611	Non-peren.	Low cropping intensity	Fresh; contr'd? (private tubewells)	Balloki Qadirabad, Rasul	Mangla
Pakpattan above TSMB Link	332	Non-peren.	Water-short; Low cropping intensity	Fresh; low and contr'd private tubewells	Balloki, Qadirabad Rasul	Mangla
Pakpattan below TSMB Link	313	Peren.	Water-short: Low cropping intensity	Saline; low Watertable	Sidhnai, Trimmu Chasma,	Tarbela Mangla
Mailsi below TSMB Link	677	Non-peren.	Water-short; fairly low cropping int.	60% fresh; low watertable	Sidhnai, Trimmu, Chasma	Tarbela Mangla
Fordwah	365	Non-peren.	Water-short low cropping intensity	Fresh;high	Suleimanke, Balloki, Qadirabad, Rasul.	Mangla
Eastern Sadiqia	913 22	Peren. Non-peren.	Water-short; low cropping intensity	Saline; low	- ditto -	Mangla
Bahawal below TSMB Link	321	Non-peren.	Water-short; low cropping intensity	Fresh; low Watertable	Sidhnai, Trimmu, Chasma	Tarbela, Mangla
Dadu, South	100	Peren.	Medium cropping intensity	Saline; low	Sukkur	Tarbela, Mangla
Khairpur, East	330	Peren.	Water-short; medium cropping intensity	Saline;contr'd by SCARP Khairpur or low	Sukkur	Tarbela, Mangla
Khairpur, West	252	Peren.	Water-short; medium cropping intensity	Saline and fresh; contr'd by SCARP Khairpur	Sukkur	Tarbela, Mangla
Rohri, Lower	877	Peren.	Water-short; low cropping intensity	Saline; low & medium	Sukkur	Tarbela, Mangla
Eastern Nara	1,453 190	Peren. Non-peren.	Water-short; low cropping intensity	Saline; low, medium & high	Sukkur	Tarbela, Mangla

1/ The groundwater status in each canal command is variable, and will probably significantly deteriorate within the next five years wherever drainage is uncontrolled.

2/ Non-per. = non-perennial regime (Kharif supplies only assured).
Peren. = perennial

3/ Estimated only, on the basis of inadequate information.

4/ Estimated only; updated information will be provided from the soil salinity and waterlogging survey under the UNDP Indus Basin Planning Project.

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

VOLUME II : IRRIGATION AND DRAINAGE

DEVELOPMENT MODES

	Development Situation	Problem To Be Resolved	Development Modes
	Existing Irrigated Areas		
1(a)	Fresh or usable groundwater zones; plentiful aquifer yield.	Drainage of high water table. (No water shortage.)	Tubewells, private and/or public, discharging into watercourses; or horizontal drainage with effluent recovery for irrigation.
1(b)	Ditto	Water shortage. (No drainage problem.)	Tubewells, private and/or public, discharging into remodeled watercourses.
1(c)	Fresh or usable groundwater zones; restricted aquifer yield.	Water shortage. (No drainage problem.) Soil Reclamation.	Tubewells, with limited canal remodeling; additional water allocation may be required for scarce water periods and Kharif.
2(a)	Saline groundwater zones.	Drainage of high water table. Water shortage. Reclamation of saline soils.	Public, saline tubewells, or horizontal open or tile drainage, with effluent disposal; canal remodeling throughout zone, with additional water allocation in kharif; canal lining in permeable soil reaches, to reduce seepage.
2(b)	Ditto	Water shortage. (No drainage problem.) Soil Reclamation.	Canal remodeling throughout zone, with additional water allocation in kharif; drainage installation in medium term.
	Potential Extensions Of Irrigation		
3(a)	Existing irrigation command(s) to be extended; groundwater at considerable depth.	Water supply.	Canal remodeling and extension; allocation of available kharif water supplies; and additional allocation of stored water for rabi.
3(b)	Additional irrigation commands to be constructed; saline groundwater at depth.	Water supply.	New canal system; allocation of available kharif water supplies; and additional allocation of stored water for rabi.
3(c)	Additional irrigation commands to be constructed; usable groundwater at varying depths.	Water supply.	Public tubewells.

NOTE: On-farm development would be required in all areas, especially watercourse improvement and more effective agricultural supporting services, with particular emphasis on watercourse enlargement in SCARP areas.

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

STATUS OF ACTION PROGRAM

Project	ISS Program Start	ISS Program Finish	Actual Status 1/
Usable Groundwater Tubewells			
Northern Region:			
Kabul River	1975	1980	Ongoing
Muzzaffargarh SCARP III	1965	1971	Complete
Thal	1973	1976	Start 1981
Rangpur	1965	1971	Complete
Haveli	1967	1969	Start 1977
Sidhnai	1969	1973	Start 1976
Mailsi Below SM Link	1971	1973	Start 1979
Bahawal Below MB Link	1972	1976	Start 1976
Panjnad And Abbasia	1968	1973	Start 1976
Upper Jhelum SCARP II	1965	1970	Complete
Lower Jhelum	1965	1971	Complete
Lower Chenab	1973	1977	Start 1978
Lower Bari Doab	1974	1980	Start 1983
Dipalpur Below BS Link	1971	1977	Start 1980
Fordwah And East Sadiqia	1971	1975	Start 1976
Qaim And Bahawal Above MB Link	1972	1976	Start 1976
MR Link	1965	1973	Start 1977
Upper Chenab	1965	1973	Start 1977
Ravi Syphon-Dipalpur Link	1970	1974	Start 1979
Dipalpur Above BS Link	1969	1973	Start 1976
Southern Region:			
Begari Sind	1972	1975	Start 1979
North West	1973	1976	Start 1976
Dadu	1973	1976	Start 1976
Khairpur West	1965	1969	Complete
Rohri North	1968	1974	Ongoing
Rohri South	1971	1975	Start 1976
Saline Groundwater Tubewells			
Panjnad And Abbasia	1973	1977	--
Lower Jhelum	1966	1971	Start 1976

1/ Starting dates based on informal Provincial and WAPDA estimates, March 1974.

Project	ISS Program Start	ISS Program Finish	Actual Status[1/]
Saline Groundwater Tubewells (Continued)			
Khairpur West	1967	1969	Completed
Khairpur East	1965	1968	Completed
Lined Channel: Gaja	1967	1970	--
Tile Drainage			
Haveli	1969	1971	Start 1976
Lower Bari Doab	1969	1971	Start 1976
Khairpur East	1973	1975	Start 1976
Tando Bago	1970	1975	--
Canal Enlargement			
Haveli	1971	1973	--
Lower Bari Doab	1969	1971	Start 1976
Ravi Syphon-Dipalpur Link	1971	1975	--
Sidhnai	1976	1981	--
Panjnad-Abbasia	1974	1982	--
Lower Jhelum	1976	1980	Start 1976
Khairpur West	1971	1974	Start 1976
Khairpur East	1972	1975	Start 1976
Rohri North	1975	1980	Ongoing
Eastern Nara	1976	1979	Start 1976
Drainage Channels			
Sukh Beas	1966	1971	--
Lower Indus Left Bank Outfall	1968	1980	Started 197[illegible]

1/ Starting dates based on informal Provincial and WAPDA estimates.

PAKISTAN

OUTLINE DETAILS OF IRRIGATION, DRAINAGE AND FLOOD CONTROL PROJECTS
PRESENTED FOR THE MISSION'S CONSIDERATION BY PROVINCIAL GOVERNMENTS AND WAPDA

TYPE OF PROJECT	PROJECT NAME	S NO.	IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION	BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)	NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION) 1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES	GENERAL COMMENTS
TUBEWELL PROJECTS:	MARDAN	1	WAPDA (Republic-Sharp)	Outline only; Project Report under preparation	Upper and Lower Swat Canals	412*	225*	905	-	-	5	5	10	20	40	120	160	1/76	Costs taken from "Green Book" but assumed based on Peshawar SCARP.	Assumed data on area to be served. Number of tubewells estimated from comparison of costs with Peshawar SCARP.
	PESHAWAR	2	WAPDA	Project Report and PCI Proforma available	Kabul River and Warsak Canals	193	140	170	5	5	5	5	3	-	23	-	23	N.A.	Costs taken from "Green Book" but presumably based on 1973 Project Report. Assumed to include electrification.	30 Wells already installed.
	SUBTOTAL TUBEWELL PROJECTS					(605)	(365)	(1,075)	(5)	(5)	(10)	(10)	(13)	(20)	(63)	(120)	(183)			
SURFACE WATER PROJECTS:	CHASMA RIGHT BANK	3	WAPDA	Project Report and PCI Proforma available	Chasma Barrage; incorporates Paharpur Canal	1,050	-	-	23	33	73	90	122	124	465	780	1,245	6/74	August 1973. Costs do not include any allowances for drainage, flood control or on-farm development. Costs deferred one year from WAPDA estimates.	Figures relate only to D.I. Khan section of canal system.
	PEHUR HIGH LEVEL LINK	4	WAPDA	Preliminary Report and PCI Proforma available	Tarbela Dam; Pehur Canal and Upper Swat Canal	134	-	-	15	29	29	15	-	-	88	-	88	6/74	May 1972. Estimates do not correctly reflect cost of intake works being carried out by Tarbela Joint Venture.	Land development costs will be high and are not included in estimate.
	SUBTOTAL SURFACE WATER PROJECTS						-	-	(38)	(62)	(102)	(105)	(122)	(124)	(533)	(780)	(1,333)			
	SUBTOTAL NORTH WEST (NWFP):						(365)	(1,075)	(43)	(67)	(112)	(115)	(135)	(144)	(616)	(900)	(1,516)			
B. NORTH (PUNJAB)																				
TUBEWELL PROJECTS:	SHORKOT KAMALIA	5	WAPDA (Republic)	Outline only; Project Report under preparation	Khanki, Trimmu and Balloki Barrages; Lower Chenab, Haveli and Lower Bari Doab Canals	395	595	595	10	49	48	41	-	-	148	-	148	6/75	March 1974 outline estimates by WAPDA. They are stated to cover all tubewells, surface and disposal drains and alternative tile drainage. It is assumed electrification costs are included.	Previous Project Report (SCARP V) by Tipton and Kalmbach Inc. covers part of area. WAPDA consider this report largely out of date.
	PANJNAD ABBASIA	6	WAPDA (Subasan)	Outline only; Project Report under preparation	Panjnad Barrage; Panjnad and Abbasia Canals	1,664	2,050	2,243	23	104	96	96	96	96	511	46	557	9/75	Same as preceding.	Previous Project Report (SCARP VI) by Tipton and Kalmbach Inc. WAPDA consider this report largely out of date.

NOTES: (1) N.A. indicates not suitable for Bank Group financing at this time: (a) ongoing projects nearing completion; (b) small projects capable financing from local sources; (c) subject to controversial technical decisions, e.g. Schwan vs. alternatives; (d) long-term prospective project unlikely ready for implementation within period under review.

(2) Where feasibility reports indicated, it does not necessarily imply planning to appraisal standards.

* Estimated by Mission.

TYPE OF PROJECT	PROJECT NAME	S NO.	IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION	BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)	NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION) 1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES	GENERAL COMMENTS
B. NORTH (PUNJAB) (CONT'D.)																				
TUBEWELL PROJECTS: (CONT'D.)	SHUJABAD	7	WAPDA (Republic)	Outline only; Project Report under preparation	Sidnai Barrage; Sidnai Canal	856	1,324	1,324	6	101	96	96	30	-	329	-	329	9/75	Same as preceding.	
	SCARP II - SALINE ZONE	8	WAPDA (Associated Consulting Engineers)	Outline only; Project Report under preparation	Rasul Barrage; Lower Jhelum Canal	548	795	795	12	49	48	48	41	-	198	-	198	6/75	Same as preceding.	Previous Project Report (SCARP II) by Tipton and Kalmbach Inc. WAPDA consider this report largely out of date.
	SCARP III - SALINE ZONE	9	WAPDA	Outline only; Project Report under preparation	Taunsa Barrage; Muzaffargarh Canal	100	226	226	7	48	-	-	-	-	55	-	55	1/75	Same as preceding.	Previous Project Report (SCARP III) by Tipton and Kalmbach Inc. WAPDA consider this report largely out of date.
	SHAMPUR	10	WAPDA	Outline only; Project Report under preparation	Rasul Barrage; Lower Jhelum Canal	128	205	205	7	43	-	-	-	-	50	-	50	6/75	Same as preceding.	
	FORDWAH SADIQIA	11	WAPDA	Outline only	Suleimanke Barrage; Fordwah and Eastern Sadiqia Canals	1,482	1,225	2,296	11	17	48	48	96	96	316	257	573	1/76	Same as preceding.	
	BAHAWAL QAIM	12	WAPDA	Outline only	Islam Barrage and Trimmu Barrage through TSMB Link System; Bahawal and Qaimpur Canals	705	400	1,135	3	8	48	42	-	-	101	182	283	1/76	Same as preceding.	
	DIPALPUR ABOVE B.S. LINK	13	WAPDA (Republic)	Outline only; Project Report under preparation	Marala through UCC Link and BRBD Link; Upper Dipalpur Canal	316	515	515	3	8	48	48	22	-	129		129	1/76	Same as preceding.	
	REMAINING UPPER RECHNA	14	WAPDA	Outline only	Marala Barrage; Marala Ravi Link and Upper Chenab Canals	1,300	1,025	1,896	8	8	10	48	96	96	266	209	475	1/77	Same as preceding.	Previous Project Report (SCARP IV) by Tipton and Kalmbach Inc. WAPDA consider this report largely out of date.
	REMAINING LOWER RECHNA	15	WAPDA	Outline only	Khanki and Qadirabad Barrages; Lower Chenab Canal	1,678	650	3,079	-	10	10	17	48	96	181	583	764	1/78	Same as preceding.	Previous Project Report (SCARP V) by Tipton and Kalmbach Inc. WAPDA consider this report largely out of date.
	MAILSI	16	WAPDA	Outline only	Trimmu through TSMB Link System and Suleimanke through UCC Link and BRBD Link	696	225	1,039	-	-	4	4	8	48	64	195	259	1/79	Same as preceding.	
	RAVI SYPHON	17	WAPDA	Outline only	Marala Barrage through UCC Link and BRBD Link	643	225	963	-	-	2	5	9	48	64	177	241	1/79	Same as preceding.	
	DIPALPUR BELOW B.S. LINK	18	WAPDA	Outline only	Balloki Barrage through B.S. I Link; Lower Dipalpur Canal	645	25	891	-	-	-	2	6	8	16	208	224	1/80	Same as preceding.	
	THAL	19	WAPDA	Outline only	Kalabagh Barrage; Thal Canal	1,640	-	2,898	-	-	-	3	10	9	22	649	721	1/81	Same as preceding.	
	D.G. KHAN	20	WAPDA	Outline only	Taunsa Barrage; D.G. Khan Canal	919	-	1,326	-	-	-	-	2	4	6	326	332	1/82	Same as preceding.	

NOTE: Where feasibility reports indicated, it does not necessarily imply planning to appraisal standards.

TYPE OF PROJECT B. NORTH (PUNJAB) (CONT'D.)	PROJECT NAME	S NO.	IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION	BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)	NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION)						PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES	GENERAL COMMENTS
									1974/75	1975/76	1976/77	1977/78	1978/79	1979/80						
TUBEWELL PROJECTS: (CONT'D.)	LOWER BARI DOAB CANAL (LBDC)	21	WAPDA	Outline only	Balloki Barrage; Lower Bari Doab Canal	1,670	-	2,520	-	-	-	-	-	6	6	621	627	1/83	Same as preceding.	
	PAKPATTAN	22	WAPDA	Outline only	Suleimanke Barrage; Pakpattan Canal	1,258	-	1,913	-	-	-	-	-	-	-	478	478	1/84	Same as preceding.	
	REPLACEMENT OF SCARP TUBEWELLS	23	PI & PD	Outline only	SCARP areas as required	-	N.A.	N.A.	-	3	4	5	6	5	23	-	23	N.A.	March 1974 outline estimates by PI & PD.	
	DISPOSAL WORKS FOR SALINE GROUNDWATER	24	PI & PD	Outline only	SCARP areas as required	-	-	-	-	2	3	3	4	3	15	-	15	N.A.	Same as preceding.	
	SUBTOTAL TUBEWELL PROJECTS:					(16,443)	(9,485)	(25,859)	(90)	(450)	(465)	(506)	(474)	(515)	(2,500)	(3,981)	(6,481)			
SURFACE WATER PROJECTS:	CHASMA RIGHT BANK	25	WAPDA	Project Report and PCI Proforma available	Chasma Barrage (New canal)	318	-	-	7	17	39	43	38	47	191	67	258	6/74	August 1973. Costs do not include any allowances for drainage, flood control or on-farm development.	Figures relate only to D.G. Khan section of canal system.
	TARBELA LEFT BANK CANAL	26	WAPDA	PCI Proforma available; (Feasibility Report should be available)	Tarbela Dam (d/s) (New canal)	58	-	-	10	25	25	-	-	-	60	-	60	6/74	From April 1973 PCI Proforma. Does not include on-farm development. Figures do not include any allowance for contingencies.	Served from regulator on left bank of river below Tarbela Dam.
	JALALPUR CANAL	27	PI & PD	PCI Proforma and Feasibility Report available	Rasul Barrage (New canal)	193	-	-	-	40	40	40	40	61	221	-	221	6/74	March 1973. On-farm development costs not included.	Will bring old inundation system downstream of Mangla under barrage control. Kharif supplies only are proposed, at least initially.
	GREATER THAL PROJECT	28	PI & PD	PCI Proforma and Feasibility Report available	Chasma Barrage through CJ Link canal (New canal)	1,560 (GCA)	-	-	-	20	20	20	20	20	100	43	143	6/74	September 1970. On-farm development costs not included.	Initially to be used for Kharif cropping only.
	DAJAL BRANCH EXTENSION	29	PI & PD	PCI Proforma available; Feasibility Report also stated to be available	Taunsa Barrage; D.G. Khan Canal	408	-	-	-	10	10	10	10	10	50	35	85	6/74	February 1972. No allowance for contingencies but some cost included for watercourse construction. General on-farm development not included.	
	SHINGLE/BOULDER LINING OF UPPER JHELUM CANAL	30	PI & PD	Not known; PCI Proforma presumed available	Mangla Headworks and Upper Jhelum Canal	-	-	-	-	2	4	4	5	5	20	-	20	N.A.	Estimate given to Mission in March 1974 but likely to be of earlier date.	
	REMODELING LOWER JHELUM CANAL	31	PI & PD	Same as preceding	Rasul Barrage; Lower Jhelum Canal	-	-	-	-	1	1	1	2	3	8	-	8	N.A.	Same as preceding.	
	REMODELING BRANCH CANALS L.J.C.	32	PI & PD	Same as preceding	Rasul Barrage; Lower Jhelum Canal	-	-	-	-	2	3	5	6	5	21	-	21	N.A.	Same as preceding	
	LINING CHANNELS EASTERN SADIQIA	33	PI & PD	Same as preceding	Suleimanke Barrage; Eastern Sadiqia Canal	-	-	-	-	1	1	2	2	2	8	-	8	N.A.	Same as preceding.	

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(2) Where feasibility reports indicated, it does not necessarily imply planning to appraisal standards.

TYPE OF PROJECT	PROJECT NAME B. NORTH (PUNJAB) (CONT'D.)	S NO.	IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION	BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)	NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION) 1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES	GENERAL COMMENTS
SURFACE WATER PROJECTS: (CONT'D.)	LINING CHANNELS NILI BAR CIRCLE	34	PI & PD	Same as preceding	-	-	-	-	-	1	1	1	1	2	6	-	6	N.A.	Same as preceding.	
	THAL CANAL LINING RENOVATION	35	PI & PD	Same as preceding	Kalabagh Barrage; Thal Canal	-	-	-	-	2	3	5	6	4	20	-	20	N.A.	Same as preceding.	
	REMODELING PARTS B.S. I AND B.S. II LINKS	36	PI & PD	Same as preceding	Balloki Barrage; B.S. I and B.S. II Links	-	-	-	-	1	2	2	2	3	10	-	10	N.A.	Same as preceding.	
	CONSTRUCTING SMALL DAMS	37	PI & PD	Same as preceding	-	-	-	-	-	5	5	5	5	5	25	-	25	N.A.	Same as preceding.	
	TAUNSA PROJECT	38	PI & PD	Ongoing project	Taunsa Barrage; Muzaffargarh and D.G. Khan Canals	1,579	-	-	33	-	-	-	-	-	33	-	33	N.A.	1961	Assumed completion of ongoing project.
	CANAL SUPPLIES TO LEFT BANK B.R.B.D. LINK	39	PI & PD	Outline planning only	Marala Barrage; New canal system from B.R.B.D. Link	48	-	-	5	-	-	-	-	-	5	-	5	N.A.	Outline estimates supplied to Mission, March 1974.	Area between Indian border and B.R.B.D. Link. Formerly supplied from India through C.B.D.C. system.
	ROCK WEIR D/S TAUNSA BARRAGE	40	PI & PD	Outline planning only	Taunsa Barrage	-	-	-	12	-	-	-	-	-	12	-	12		Outline estimates supplied to Mission, March 1974.	Remedial works to stabilize barrage.
	REMODELING IRRIGATION CHANNELS (Several small projects; channel capacities not to be increased)	41	PI & PD	Ongoing projects	-	-	-	-	8	-	-	-	-	-	8	-	8		1965-1973	Assumed completion of ongoing projects.
	REMODELING SIDHNAI CANAL	42	WAPDA	Outline planning only	Sidhnai Barrage; Sidhnai Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	
	REMODELING LOWER JHELUM CANAL	43	WAPDA	Same as preceding	Rasul Barrage; Lower Jhelum Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	(Conflicts with Irrigation Department Punjab projects; see Serial No's 31 and 32.)
	REMODELING HAVELI CANAL	44	WAPDA	Same as preceding	Trimmu Barrage; Haveli Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	
	REMODELING ABBASIA CANAL	45	WAPDA	Same as preceding	Panjnad Barrage; Abbasia Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	
	REMODELING PANJNAD CANAL	46	WAPDA	Same as preceding	Panjnad Barrage; Panjnad Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	
	REMODELING CENTRAL BARI DOAB CANAL	47	WAPDA	Same as preceding	Marala Barrage through U.C.C. Link and B.R.B.D. Link; Central Bari Doab Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	
	LINING EASTERN SADIQIA CANALS	48	WAPDA	Same as preceding	Suleimanke Barrage; Eastern Sadiqia Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.	N.A.	N.A.	N.A.	12/76*	No estimates given.	(Possible duplication with Irrigation Department Punjab project; see Serial No. 33.)
	LINING FORDWAH CANALS	49	WAPDA	Same as preceding	Suleimanke Barrage; Fordwah Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	
	LINING NORTHERN BRANCH L.J.C.	50	WAPDA	Same as preceding	Rasul Barrage; Lower Jhelum Canal	-	-	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	12/76*	No estimates given.	

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* Estimated by Mission.

TYPE OF PROJECT	PROJECT NAME	S NO.	IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION	BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)	NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION)						PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES	GENERAL COMMENTS
B. NORTH (PUNJAB) (CONT'D.)									1974/75	1975/76	1976/77	1977/78	1978/79	1979/80						
SURFACE WATER PROJECTS: (CONT'D.)	TRANS INDUS LINK (K.J.C.B. LINK)	51	WAPDA	Same as preceding	From Kalabagh Barrage	-	-	-	-	-	-	-	-	-	-	1,240	1,240	19/80*	Outline estimate supplied to Mission. Estimate made 1966/67.	Planning only before 1980.
	SUBTOTAL SURFACE WATER PROJECTS:								(75)	(127)	(154)	(138)	(137)	(167)	(798)	(1,385)	(2,183)			
HORIZONTAL DRAINAGE PROJECTS: (TILE AND SURFACE)	SHORKOT KAMALIA TILE DRAINAGE PILOT	52	WAPDA	Same as preceding	Trimmu Barrage; Haveli Canal	37	-	-	-	4	5	5	3	-	17	-	17	6/75	1967 Cost estimate.	
	LBDC TILE DRAINAGE PILOT	53	WAPDA	Same as preceding	Balloki Barrage; Lower Bari Doab Canal	45	-	-	-	-	-	-	-	-	-	22	22	6/80*	1967 Cost estimate.	
	INCREASING CAPACITY OF STRUCTURES ON FAQIRIAN SILLANWALI DRAIN	54	PI & PD	Not known; PCI Proforma presumed available	-	-	-	-	-	5	10	10	12	13	50	-	50	N.A.	Estimate given to Mission in March 1974, but likely to be of earlier date.	
	KHAIRWALA DRAINAGE SYSTEM	55	PI & PD	Same as preceding	-	-	-	-	-	2	3	5	5	5	20	-	20	6/76*	Same as preceding	
	PARARANG DRAINAGE SYSTEM	56	PI & PD	PCI Proforma and Feasibility Report available	-	-	-	-	4	6	9	10	-	-	29	-	29	6/74	December 1973 estimate revised March 1974 for Mission. Phasing assumed.	
	PANDOKI DRAINAGE SYSTEM	57	PI & PD	Ongoing project	-	-	-	-	2	-	-	-	-	-	2	-	2	N.A.	1959	Assumed completion of ongoing project.
	REMODELING HUDIARA DRAINAGE SYSTEM	58	PI & PD	Ongoing project	-	-	-	-	10	-	-	-	-	-	10	-	10	N.A.	December 1971.	Same as preceding.
	BAIWIND DRAINAGE SYSTEM.	59	PI & PD	Ongoing project	-	-	-	-	5	5	5	6	-	-	21	-	21	N.A.	December 1972.	Same as preceding.
	REMODELING RECHNA OUTFALL DRAINS	60	PI & PD	Ongoing project	-	-	-	-	5	-	-	-	-	-	5	-	5	N.A.	1962	Same as preceding
	SATIANA SAMUNDRI DRAINAGE SYSTEM	61	PI & PD	Ongoing project	-	-	-	-	11	12	-	-	-	-	23	-	23	N.A.	May 1973.	Same as preceding
	SUBTOTAL HORIZONTAL DRAINAGE PROJECTS:								(37)	(34)	(32)	(36)	(20)	(18)	(177)	(22)	(199)			
FLOOD PROTECTION PROJECTS:	FLOOD BUNDS	62	PI & PD	Outline planning only	-	-	-	-	55	75	120	130	145	155	680	320	1,000		Estimate given to Mission March 1974. Phasing assumed. Includes Rs 12 million in 1974/75 for ongoing works.	
	RIVER TRAINING WORKS-TRIMMU BARRAGE	63	PI & PD	Not known; PCI Proforma assumed available	Trimmu Barrage	-	-	-	-	1	2	2	2	-	7	-	7	N.A.	Estimate given to Mission in March 1974, but likely to be of earlier date.	
	SUBTOTAL FLOOD PROTECTION PROJECTS:								(55)	(76)	(122)	(132)	(147)	(155)	(687)	(320)	(1,007)			
	SUBTOTAL NORTH (PUNJAB):						(9,485)	(25,859)	(257)	(687)	(773)	(812)	(778)	(855)	(4,162)	(5,708)	(9,870)			
	SUBTOTAL NORTHERN ZONE:						(9,850)	(26,934)	(300)	(754)	(885)	(927)	(913)	(999)	(4,778)	(6,608)	(11,386)			

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* Estimated by Mission.

TYPE OF PROJECT	PROJECT NAME	S NO.	IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION	BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)	NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION)						PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES	GENERAL COMMENTS
SOUTHERN ZONE A. SOUTH (SIND)									1974/75	1975/76	1976/77	1977/78	1978/79	1979/80						
TUBEWELL PROJECTS:	ROHRI NORTH	64	WAPDA	Ongoing project	Sukkur Barrage; Rohri Canal	686	650	650	40	200	110	-	-	-	350	-	350	N.A.	September 1973.	Ongoing project. Tubewell numbers assume 570 wells already installed. Assume additional wells follow. Hunting/MacDonald plans.
	LARKANA PILOT PROJECT	65	WAPDA	Ongoing project	Sukkur Barrage; Right Bank canals	5	-	-	1	-	-	-	-	-	1	-	1	N.A.	1973	35 Tubewells assumed already installed.
	SHIKARPUR PILOT PROJECT	66	WAPDA	Ongoing project	Sukkur Barrage; Right Bank canals	14	-	-	1	-	-	-	-	-	1	-	1	N.A.	1973	50 Tubewells assumed already installed.
	SUKKUR RIGHT BANK FRESH GROUNDWATER	67	WAPDA	Project planning report available	Sukkur Barrage; Right Bank canals	130	352	352	3	78	100	11	-	-	192	-	192	12/76*	1971	
	GHOTKI	68	WAPDA (ASCON-BOLAN)	Same as preceding	Gudu Barrage; Ghotki Canal	398	1,388	1,388	3	37	76	120	120	-	356	-	356	6/76	1970	Hunting/MacDonald report available. WAPDA considers report largely out of date.
	ROHRI SOUTH	69	WAPDA	Same as preceding	Sukkur Barrage; Rohri Canal	473	1,492	1,492	2	46	49	120	122	-	339	-	339	12/76*	1969	Same as preceding.
	GUDU RIGHT BANK FRESH GROUNDWATER	70	WAPDA	Not known; likely to be outline planning only	Gudu Barrage; Right Bank canals	160	180	440	-	-	-	-	-	100	100	140	240	6/77*	Estimate given to Mission in March 1974, but likely to be of earlier date.	No data on area and number of tubewells given. Figures prorated from Sukkur Right [illegible] Fresh Ground-water Project.
	SUBTOTAL					(1,868)	(4,062)	(4,372)	(50)	(361)	(335)	(251)	(242)	(100)	(1,339)	(140)	(1,479)			
SURFACE WATER PROJECTS:	REMODELING KHAIRPUR EAST AND WEST FEEDERS	71	WAPDA	Project report available	Sukkur Barrage; Khairpur East and West feeders					10	30	20	[illegible]	4	73		73	6/74*	Estimate given to Mission in March 1974, but likely to be of earlier date.	
	MAKHI FARASH LINK	72	SI & PD	Outline only	Sukkur Barrage; Left Bank canals	-	-	-	1	2	21	22	22	22	90	-	90	N.A.	Outline estimate given to Mission in March 1974, but likely to be of earlier date.	Part of alternative to Sehwan Complex, which is still proposed by WAPDA.
	NARA JAMRAO KOTRI LINK	73	SI & PD	Outline only	Sukkur Barrage; Left Bank canals	-	-	-	4	4	48	48	48	48	200	-	200	N.A.	Same as preceding.	Same as preceding.
	REMODELING ROHRI CANAL	74	SI & PD	Outline only	Sukkur Barrage; Rohri Canal	-	-	-	6	6	72	72	72	72	300	-	300	N.A.	Same as preceding.	Same as preceding.
	REMODELING DADU CANAL	75	SI & PD	Outline only	Sukkur Barrage; Dadu Canal	-	-	-	3	3	36	36	36	36	150	-	150	6/76*	Same as preceding.	
	SUBTOTAL SURFACE WATER PROJECTS:								(15)	(25)	(207)	(198)	(187)	(182)	(814)	(-)	(814)			
HORIZONTAL DRAINAGE PROJECTS: (TILE AND SURFACE)	LEFT BANK OUTFALL DRAIN PHASE I	76	WAPDA	Ongoing project	Sukkur and Kotri Barrages; Left Bank canals	-	-	-	40	50	50	50	39	-	229	-	229	6/74	1972	First phase of project. Construction commenced at outfall end.
	LEFT BANK OUTFALL DRAIN PHASE II	77	WAPDA	Project report available	Sukkur and Kotri Barrages; Left Bank canals	-	-	-	-	-	-	-	50	50	100	100	200	6/74	1972 *	
	LARKANA-SHIKARPUR STAGE II	78	WAPDA	Ongoing project	Sukkur Barrage; Right Bank canals	490	-	-	19	-	-	-	-	-	19	-	19	N.A.	November 1972.	Completion of ongoing project.

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TYPE OF PROJECT	PROJECT NAME	S NO.	IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION	BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)	NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION) 1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES	GENERAL COMMENTS
A. SOUTH (SIND) (CONT'D.)																				
HORIZONTAL DRAINAGE PROJECTS: (TILE AND SURFACE) (CONT'D.)	LARKANA-SHIKARPUR STAGE III	79	WAPDA	Project report available	Sukkur Barrage; Right Bank canals		-	-	-	1	2	1	-	-	4	-	4	N.A.	Estimate given to Mission in March 1974, but likely to be of earlier date.	
	KHAIRPUR TILE DRAINAGE	80	WAPDA	Project report available but to be updated	Sukkur Barrage; Khairpur East Canal	N.A.	-	-	20	20	20	6	-	-	66	-	66	12/74	Same as preceding.	
	GAJA TILE DRAINAGE	81	WAPDA	Outline only	Kotri Barrage; Left Bank canals	N.A.	-	-	-	3	8	8	8	8	35	18	53	6/76	Same as preceding.	
	DADU NORTH AND SOUTH	82	WAPDA	Outline only	Sukkur Barrage; Dadu Canal	N.A.	-	-	2	3	3	3	3	3	17	153	170	6/80*	Same as preceding.	
	RIGHT BANK OUTFALL DRAIN	83	WAPDA	Outline only	Sukkur and Kotri Barrages; Right Bank canals	-	-	-	2	6	6	6	6	4	30	-	30	N.A.	Same as preceding.	
	KANDKOT-THUL	84	WAPDA	Outline only		-	-	-	2	2	2	2	5	6	19	361	380	6/80*	Same as preceding.	
	KOTRI BARRAGE DRAINAGE	85	WAPDA	Ongoing project	Kotri Barrage Left Bank canals	-	-	-	20	44	44	44	44	44	240	144	384	6/74	Same as preceding.	
	SUBTOTAL HORIZONTAL DRAINAGE PROJECTS: (TILE AND SURFACE)								(105)	(129)	(135)	(120)	(155)	(115)	(759)	(776)	(1,535)			
FLOOD PROTECTION PROJECTS:	FLOOD BUNDS PHASE I	86	SI & PD	Outline only		-	-	-	100	150	150	-	-	-	400	-	400		Outline estimates given to Mission in March 1974.	
	FLOOD BUNDS PHASE II	87	SI & PD	Outline only		-	-	-	-	-	-	280	270	260	810	390	1,200		Same as preceding.	
	SUBTOTAL FLOOD PROTECTION PROJECTS:								(100)	(150)	(150)	(280)	(270)	(260)	(1,210)	(390)	(1,600)			
	SUBTOTAL SOUTH (SIND):						(4,062)	(4,322)	(270)	(665)	(827)	(849)	(854)	(657)	(4,122)	(1,306)	(5,428)			
B. SOUTHWEST (BALUCHISTAN)																				
TUBEWELL PROJECTS:	GROUNDWATER DEVELOPMENT FOR AGRICULTURE	88	WAPDA	Outline only		665	5,300	9,500	-	44	265	265	265	332	1,171	929	2,100	3/76	Outline estimates given to Mission in March 1974. Do not include electrification and generation costs.	Separable projects may be brought in ahead of the total plan. First may be ready by date shown.
	SUBTOTAL TUBEWELL PROJECTS:					(665)	(5,300)	(9,500)	(-)	(44)	(265)	(265)	(265)	(332)	(1,171)	(929)	(2,100)			
SURFACE WATER PROJECTS:	PAT FEEDER	89	WAPDA	Outline only; PCII Proforma available	Gudu Barrage; Pat Feeder	300		-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	6/80*	No estimate available, but project preparation and construction scheduled to be completed by 1980.	
	SUBTOTAL SURFACE WATER PROJECTS:								(N.A.)	(N.A.)	(N.A.)	(N.A.)	(N.A.)	(N.A.)	(N.A.)	(N.A.)	(N.A.)			
HORIZONTAL DRAINAGE PROJECTS: (TILE AND SURFACE)	HAIRDIN PILOT PROJECT	90	WAPDA	Outline only; Project planning in hand	Gudu Barrage; Pat Feeder	-		-	10	10	-	-	-	-	20	-	20	6/75	Outline estimate given to Mission in March 1974, but likely to be of earlier date.	

NOTES: (1) N.A. indicates not suitable for Bank Group financing at this time: (a) ongoing projects nearing completion; (b) small projects capable financing from local sources; (c) subject to controversial technical decisions, e.g. Sehwan vs. alternatives; (d) long-term prospective project unlikely ready for implementation within period under review.

(2) Where feasibility reports indicated, it does not necessarily imply planning to appraisal standards.

* Estimated by Mission.

TYPE OF PROJECT	PROJECT NAME B. [illegible]	S NO.		IMPLEMENTING AGENCY (AND CONSULTANT)	STATUS OF PROJECT PREPARATION		BARRAGE/CANAL SYSTEMS CONCERNED	CCA AFFECTED ('000 ACRES)		NO. OF TUBEWELLS 1974-1980	TOTAL NO. OF TUBEWELLS	PROPOSED PHASING OF EXPENDITURE TO 1979/80 (RS MILLION) 1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	PROJECT CAPITAL COST 1974-1980 (RS MILLION)	PROJECT COMPLETION COST POST 1980 (RS MILLION)	TOTAL REMAINING PROJECT COST FROM 1974 (RS MILLION)	ESTIMATED AVAILABILITY OF PROJECT FEASIBILITY REPORT	DATE AND STATUS OF COST ESTIMATES		GENERAL COMMENTS
	PAT FEEDER DRAINAGE	91		WAPDA/ADC/ BI & PD	Ongoing project		Gudu Barrage; Pat Feeder	588			-	-	-	-	26	26	27	79	78	157	6/77	Date of estimate not known, but likely to be somewhat earlier than 1974.		
	SUBTOTAL HORIZONTAL DRAINAGE PROJECTS:											(10)	(10)	(0)	(26)	(26)	(27)	(99)	(78)	(177)				
	SUBTOTAL SOUTHWEST: (BALUCHISTAN)									(5,300)	(9,590)	(36)	(80)	(291)	(291)	(291)	(359)	(1,348)	(929)	(2,277)				
	SUBTOTAL SOUTHERN ZONE:									(9,362)	(13,822)	(306)	(745)	(1,118)	(1,140)	(1,145)	(1,016)	(5,470)	(2,235)	(7,705)				
	TOTAL PAKISTAN: (EXCLUDING STORAGE PROJECTS)									(19,212)	(40,756)	(606)	(1,499)	(2,003)	(2,067)	(2,058)	(2,015)	(10,248)	(8,843)	(19,091)				
STORAGE PROJECTS:	KHANPUR DAM	92		WAPDA	Ongoing project			77				76	76	-	-	-	-	152	-	152	N.A.	1972. Estimated cost to complete works.		
	KALABAGH DAM	93		WAPDA (ACE)	Project report under preparation		-	-		-	-	-	-	-	-	-	-	-	6,000	6,000	N.A.	Planning only during period to 1980. No cost estimate for planning available.		
	THAL RESERVOIR	94		WAPDA	Outline planning only		-	-		-	-	-	-	-	-	-	-	-	N.A.	N.A.	N.A.	No cost estimate available. Planning only likely in period up to 1980.		
	CHOTIARI RESERVOIR	95		SI & PD	Outline only			-		-	-	5	5	36	36	36	36	150	-	150	N.A.	Outline estimate given to Mission in March 1974, but likely to be of earlier date.		Part of alternative to Sehwan Complex which is proposed by WAPDA.
	SURFACE STORAGE PROJECTS (BALUCHISTAN)	96		WAPDA	Outline only			-		-	-	-	5	50	50	50	50	205	35	240	N.A.	Same as preceding.		
	SUBTOTAL STORAGE PROJECTS:									-	-	(79)	(84)	(86)	(86)	(86)	(86)	(507)	(6,035)	(6,542)				
	TOTAL PAKISTAN: (INCLUDING STORAGE PROJECTS)									19,212	40,756	659	1,557	2,063	2,153	2,144	2,101	10,677	14,956	25,633				

NOTES: (1) N.A. indicates not suitable for Bank Group financing at this ti[illegible] small projects capable financing from local sources; (c) subject to controversial technical decisions, e.g. Sehwan [illegible] unlikely ready for implementation within period under review.

(2) Where feasibility reports indicated, it does not necessarily imply planning to appraisal standards.

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW
IRRIGATION AND DRAINAGE

UNDP INDUS BASIN PLANNING PROJECT

Introduction

1. Institutional framework and funding. The Federal Ministry of Fuel, Power and Natural Resources has overall responsibility for the Planning Project. Most of the planning and reporting work will be carried out by WAPDA which is a semi-autonomous agency within the Ministry, in coordination with other participating agencies and with representatives of the Provincial Government departments. Primary responsibility for actually carrying out the Project will be held by the Master Planning Division of WAPDA. The Division will be expanded, and considerable support will be provided to the Division by other WAPDA units, including the Central Monitoring Organization, the Power Division and Computer Centre; by the Planning Division of the Federal Ministry of Finance, Planning and Economic Affairs; the Federal Ministry of Food and Agriculture; and by relevant Departments of the Provincial Governments. The Bank, as Executing Agency on behalf of UNDP, has engaged Harza Engineering International as its consultants for the Project, to provide additional technical support and guidance to WAPDA.

2. Foreign exchange funds for surveys and investigations, and for securing the support of outside consultants, were sought and obtained from the UNDP. Arrangements in this connection, and the contribution which UNDP and the Bank Group would make through technical assistance and other means, were cleared with the Government by November 1974. The outlines of the surveys and special studies which follow are indicative of the field investigations which will be carried out under the Planning Project. The production of a new air photo survey of the whole of the irrigated area of the Indus Basin, to assist the field surveys and to update the Colombo Plan survey of 1955, will be considered by the Bank for funding under an on-going project.

Program of Planning Project

3. Including a four-to five month mobilization period, the Planning Project is being executed over a three-year period which began in September 1975. Project review and planning will be started as soon as the necessary organizations are in place and will be a continuous activity. Interim reports will provide up-to-date lists of specific irrigation and drainage projects ready for implementation and will indicate the scope and cost of investigations necessary to complete the preparation of further projects over five-year and ten-year periods (1976-81 and 1976-86). While interim reports will be prepared by January 1975 and June 1976, the report outlining the revised Action Program for the next ten years or so, and including recommendations for medium and long-term water distribution policies, will not be ready before the latter part of 1978.

4. During its discussions with WAPDA and the Provincial authorities, the Irrigation and Drainage Review mission identified in outline some 96 irrigation, drainage and flood protection construction projects which were either ongoing or in various stages of preparation; they are listed in Annex 3. A large proportion of these projects were identified in the original ISS program, and the following grouping by Provinces is indicative of their state of preparation.

Irrigation, Drainage and Flood Control	Southern Region		Northern Region		
	Baluchistan	Sind	NWFP	Punjab	Total
Ongoing projects	1	5	1	6	13
Feasibility reports available	-	4	2	1	7
Reports under preparation	1	4	1	12	18
Outline reports only	2	11	-	40	53
	4	24	4	59	91
Surface storage (Outline reports only)	1	1	-	3	5
	5	25	4	62	96

Other projects being prepared by the Federal Ministry of Food and Agriculture and the Provincial Departments of Agriculture, as well as preliminary suggested projects put forward by the Irrigation and Drainage Review mission, are not included in the tabulation.

5. One of the early objectives of the Planning Project will be to list the projects already provisionally approved by GOP for investigation, and classify them along the following lines:-

(a) the highest priority projects fully prepared for early implementation;

(b) high priority projects requiring feasibility studies before implementation;

(c) projects requiring additional investigations, possibly including pilot developments, designed or intended to resolve undetermined technical issues;

(d) interdependent projects, requiring joint studies to enable sound, related investment decisions be made without pre-empting subsequent developments; and

(e) promising project possibilities not yet investigated, particularly those aimed at improvement of on-farm infrastructure and supporting services.

With the aid of this classification, it will be possible for WAPDA to formulate a preliminary version of the revised Action Program, for projects in the first and second five-year periods covering irrigation, drainage, on-farm development and flood protection; to make recommendations on provisional, short-term arrangements for the distribution and use of stored water releases from Mangla and Tarbela within the Provinces consistent with the preliminary proposals for project investments; and to identify a program of high priority work for the preparation and evaluation of all provisionally approved projects other than those of the highest priority, including the consideration of feasible alternative methods of achieving the development objectives.

6. On the basis of this preliminary formulation, more definitive technical planning will proceed after WAPDA and the Ministries concerned have established the following prerequisites:

(a) the components and methodologies to be adopted for detailed project evaluation;

(b) the Governments' estimates of projected limits of annual financial outlay and trained staff availability for sector development;

(c) the feasible increases in capacity for project implementation and in the sector's absorption capacity; and

(d) the development policies of the Federal and Provincial Governments which will affect technical planning decisions.

The latter input requirement for the Planning Project will call for effective direction and support to WAPDA from the national board with appropriate powers, which Federal Government has agreed to establish (paragraph 4.13 and Annex 5).

Special Surveys and Studies

7. A soil salinity and waterlogging survey and a watercourse chak farming survey will provide the basic information needed in each hydrological unit or canal command, to enable the state of waterlogging, soil salinity and agriculture to be updated. The rates of change of these technical and socio-economic factors can then be assessed from previous surveys, as inputs for consideration of reclamation priorities. The surveys will enable project outlines to be revised as necessary, the irrigation and drainage requirements recalculated, and the project costs and benefits subsequently re-estimated for purposes of evaluation of the projects.

8. Soil Salinitry and Waterlogging Survey. Up-to-date, detailed country-wide data on the location, extent and severity of the soil salinity and waterlogging problems are essential in order to establish appropriate priorities for the planning and implementation of projects for their improvement. Almost all of the irrigated land in Pakistan south of the 15-inch rainfall isohyet is slightly to moderately saline; much of it is highly saline and consequently has low productivity. Considerable areas of saline soils are also found in higher rainfall areas that are poorly drained. Under the Planning Project, an investigational program designed to identify the situation as it has changed over the last 10 years, will be carried out over a period of about two years with the aid of the new air photo coverage.

9. Watercourse Chak Farming Survey. Effective decision-making with respect to national planning for agricultural development and water control investments in the Indus Basin will not be possible without up-to-date and reliable information including on-farm irrigation requirements, cropping intensities, yields, farming practices, modern inputs usage, farm gate prices, on-farm production costs and socio-economic factors in each canal command. Under both the Lower Indus Project and the ISS, detailed field studies were undertaken on about 80 watercourses through Sind and Punjab, and much of the data obtained needs to be updated and supplemented. This will be carried out in 60 selected watercourse chaks.

10. Analyses of water distribution and use. Reactivation of some of the computer models developed as part of the ISS may help ensure internal consistency of the proposals arising from the revised Action Program. In particular, consideration will be given to running the ISS computerized hydrological and agricultural development analyses with up-to-date assumptions regarding river flows and development proposals. Two such simulation models have been developed by Harza and Gibb, respectively. These models allowed the simulation of the Indus Basin irrigation and power systems with monthly time intervals, on the basis of alternative assumptions regarding sequential seasonal river flows. The models were used to test the ISS Action Program proposals for integrated surface and groundwater, power, energy generation and agricultural development, in terms of the estimated monthly water requirements over a 20-year period. A rerun of related analyses and models may be undertaken as part of the UNDP Indus Basin Planning Project.

TECHNICAL NOTE NO. 1

GLOSSARY OF ABBREVIATIONS

CCA	-	Cultivable Commanded Area
CJ	-	Chasma-Jhelum Link
IPD	-	Irrigation and Power Department
MDO	-	Mangla Dam Organization
NWFP	-	North West Frontier Province
RQBS	-	Rasul-Qadirabad-Balloki-Suleimanke Link
TP	-	Taunsa-Panjnad Link
TSMB	-	Trimmu-Sidhnai-Mailsi-Bahawal Link
WAPDA	-	Water and Power Development Authority
WMC	-	Water Management Cell

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

TECHNICAL NOTE NO. 1

THE INDUS BASIN SURFACE WATER SYSTEM

INDEX

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

TECHNICAL NOTE NO. 1

THE INDUS BASIN SURFACE WATER SYSTEM

I. HISTORICAL SETTING

Background to Irrigation in Pakistan

1.01 Evidence from Mohenjodaro and other archaeological sites in Pakistan shows that as early as 1000 B.C. land near the main rivers of the Indus plains was being cultivated under flood irrigation. The first canals were constructed some five or six centuries ago and extended under the great Moghul emperors. These early canals were inundation channels some of which were of considerable size. They delivered water to the fields when rivers were high in summer, but tended to be unpredictable in operation and subject both to frequent breaches and serious siltation problems.

1.02 The canal system which exists today was started in the nineteenth century under the British administration. Weirs and barrages were constructed so that the supply of irrigation was no longer so dependent on natural variations in river level and new canal systems were excavated incorporating the old inundation channels. Since independence in 1947, Pakistan has continued to extend the canal system and almost all the areas previously irrigated from inundation channels are now served from the river barrages.

1.03 The availability of water varies through the basin but in general demand exceeds supply. Water shortages occur for two reasons, firstly because actual river flows fall below design allocations at times of low river stage and also due to the design of the canal systems. The canals were generally built to command as much land as possible, particularly crown waste, and for this reason, although allowance was made for full cropwater requirements, the design cropping intensities were low, in some cases less than half that which the land would be capable of supporting.

1.04 In the early periods of irrigation development in the nineteenth century, the canal systems were designed on a perennial basis with water delivered all the year round. Later, with increasing demands on rabi river supplies, some canals were designed to operate non-perennially in kharif only. The newest canal systems which are served from the barrages at Taunsa, Gudu and Kotri, are largely non-perennial.

1.05 Non-perennial canals are generally operated from mid April to mid October, although some run at other times. In a year of low kharif supplies the period during which the canals are open may be curtailed but, conversely, in a year of good rabi river flows, non-perennial canals may be given supplies outside their normal season. Apart from the occasional canal irrigation, rabi crops in the non-perennial areas are watered by rainfall, Persian wheels and tubewells although in the non-perennial rice areas of Sind there is substantial cropping on residual soil moisture.

1.06 Established water rights are the main reason for the distinction between perennial and non-perennial areas in the canal commands. 57% of the culturable commanded area (CCA) in Sind has been designed for perennial supplies whereas 45% of the Thal Doab and Indus Right Bank area in the Punjab is designated as perennial. In the remainder of Punjab, the proportion of perennial areas is higher towards the north as can be seen from the following percentages of CCA:

Chaj Doab	81% perennial
Rechna Doab	75% "
Bari Doab	60% "
Sutlej & Panjnad Left Bank	50% "

Other major factors relevant to the design of some canal systems in the Punjab, particularly the Sutlej Valley system, were the provision of domestic water for colonization and the availability of alternative sources of rabi irrigation. Areas of fairly shallow, fresh groundwater were generally designated as non-perennial, as it was considered that Persian wheels and tubewells could be used both for drinking water and for rabi irrigation, as had been the practice in the inundation canal areas. On the other hand perennial supplies were generally provided where groundwater was deep, saline or brackish and considered unsuitable for irrigation. In the Vale of Peshawar all the canals effectively receive perennial supplies.

1.07 The delivery capacity of the canal systems varies according to the original design of the project. However one fairly general feature is that non-perennial channels receive a higher allowance per unit of CCA than perennial channels within the same system. This was intended as a form of compensation for the seasonal nature of supplies. Due to shortages of supplies, a widespread practice of limited, intentional under-irrigation has been adopted which maintains cropping intensities above design levels and enables cultivators to obtain higher total production from available supplies than by applying the full irrigation requirement to a smaller area. Apart from this deliberate under-watering, crops frequently suffer from the unreliability of supplies and unforeseen water shortages have often caused loss of production especially in the newer canal projects which generally have a lower priority for the allocation of surface water. A side effect of the unreliability of supplies has been that cultivators habitually over-irrigate when supplies are abundant as a safeguard against possible shortages later, although conversely some under-irrigation is practiced in early kharif in anticipation of better supplies in later months of the season.

The Present Irrigation System

1.08 The irrigation system of the Indus plains commands a gross area of about 38 million acres and comprises some 38 thousand miles of canals. Following completion of the major Indus Basin Project (IBP) works constructed under the terms of the Indus Water Treaty of 1960, the main and link canals are being served from two dams, sixteen barrages and three weirs.

1.09 The total irrigated area of Pakistan is served by 42 canal commands, of which four were partitioned by the IBP link canals. The total CCA is officially stated to be about 33.5 million acres although, in practice, no more than about 25 million acres receive surface water supplies; the remaining land, which is culturable waste, 1/ is largely in the Lower Indus area of Sind. Individual canal commands vary considerably in size from relatively small units like Qaim, with 40 thousand acres, to the largest command, Lower Chenab, with nearly 3 million acres. About 20 million acres of the total CCA are designated for perennial supplies and 13 million acres for non-perennial supplies. In addition several small areas of land are still irrigated by inundation canals and these amount to about 100 thousand acres.

1.10 A barrage may feed one or more main or link canals. The main canals serve the irrigated areas directly, whereas the links perform bulk transfers of water from the major river sources on the western side of the Punjab to the vast irrigated areas to the east. Both link and main canals are large by any standards - there are fifteen of them with capacities in the range 10,000 to 22,000 cubic feet per second (cusecs).

1.11 A main canal and its branches feed a number of distributaries or minor canals which have capacities generally ranging from 200 down to five cusecs. At intervals of half to one mile along the minor canals, irrigation outlets serve the farmers' watercourses. The capacity of an outlet is usually between one and four cusecs and a watercourse area, or "chak", is generally between 150 and 600 acres. The ratio between outlet capacity and chak area is determined for a given climatic zone by the cropping pattern and design intensity originally assumed.

1.12 A feature of the canal systems is the absence of intermediate regulators along distributaries and minors. These channels are designed to run in a form of hydraulic equilibrium, maintaining sufficient head of water on each outlet to give it an almost constant discharge. For this reason they cannot be run at less than about 3/4 full capacity without creating an inequitable distribution of supplies to the chaks they command. The main canals, on the other hand, generally have sufficient control structures to permit variations in flow down to about one third full

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1/ Within the commanded area of main canals, but not yet developed for irrigation.

capacity when the canals are in good working condition. In extreme cases, certain main canals may run at as little as one tenth full capacity.

1.13 Thus the existing system has been designed to take a variable flow from the rivers when the discharge is below full supply level, yet deliver a relatively constant flow at the field. Inevitably this necessitates a system of rotated closures of distributaries during periods when less than full supply conditions are in operation, either owing to reduced availability or reduced demand. Within the chak a cultivator usually has a fixed time during which he is entitled to the whole of the flow in the watercourse channel.

1.14 The only surface water storage developments completed to date have been Warsak dam on the River Kabul and Mangla dam on the River Jhelum, and at Chasma Barrage on the Indus. Warsak is used primarily as a regulator for hydro-electric generation and has a negligible capacity from the agricultural standpoint. The commissioning of Mangla dam in 1967, with an initial live capacity of over 5 Mac-ft, completed the first major storage scheme. However, this stored water is intended to serve primarily as replacement for the loss of the flows in the Ravi, Sutlej and Beas rivers diverted upstream in India. The addition of Tarbela storage in 1976-77 will provide over 9 Mac-ft of extra releases during the rabi season - a very significant increase in quantity when compared with the present average rabi canal withdrawals of about 28.5 Mac-ft throughout the basin.

History of Water Agreements on the Indus and its Tributaries

1.15 The early inundation canals from the Indus and its tributaries took such supplies as the river levels permitted, but these withdrawals were only a small proportion of the total supplies available. The introduction of weir controlled canals in the nineteenth century enabled supplies to be drawn throughout the year. During the rabi season when river flows were low, weir controlled canal withdrawals became a significant proportion of the total river supplies, and in 1919 the Indian Cotton Committee reported on shortages which might occur in the proposed Sukkur Barrage Project. Controversy over the distribution of the waters of the Indus and its tributaries may be said to date from the report of this Committee. The lack of data relating to the available river supplies was the cause of uncertainty and in 1921 Sir Thomas Wood, the then Inspector General of Irrigation, set up a system of gauging stations on the Indus and its tributaries. In the same year, although only scant data were available, the Government of India sanctioned the Sutlej Valley Project. The Agreement between the interested parties relating to this project, which became known as the Tripartite Agreement, was concluded in 1920 between the Governments of the Punjab, Bikaner State and Bahawalpur State.

1.16 In 1923 the Sukkur Barrage Project was sanctioned and the erstwhile Government of India expressed the opinion that no difficulties would be encountered by constructing the Sutlej Valley and Sukkur Barrage Projects at the same time. However, after completion of the Sutlej Valley Project, it was found that river supplies were well below those predicted and thus the allocations set out in the Tripartite Agreement could not be supplied from the Sutlej River. The Indus Discharge Committee, which had been set up in 1921 to scrutinize the results of the discharge observations being made, held its second meeting in 1929. The committee examined the effect that further irrigation withdrawals in the Punjab would have on the Sukkur Barrage Canals and recommended limits for withdrawals which should not be exceeded until 1939 when more reliable discharge data would become available. It was then becoming apparent that the existing arrangements for canal withdrawals from the Indus and its tributaries were unsatisfactory and that revisions were urgently required.

1.17 In 1935 a committee of the Central Board of Irrigation was appointed by the Government of India to report on the distribution of the waters of the Indus and its tributaries. This committee, known as the Anderson Committee, consisted of two independent members appointed by the Government of India and representatives of all the provinces and states dependent on Indus waters. The committee examined the whole problem of water allocations to the existing and projected canal systems. They made a number of recommendations, most of which were accepted by the member governments and confirmed by the Government of India in 1937. The roots of the present procedures for allocations lie in the recommendations of the Anderson Committee.

1.18 However, in 1939 the Government of Sind approached the Government of India claiming that implementation of the Anderson Committee report would adversely affect their irrigation supplies. The Indus Commission, known as the Rau Commission which was set up under Mr. Justice Rau to investigate these complaints, largely supported the Anderson Committee report but recommended the construction of barrages at Gudu and Kotri to protect withdrawals of the Sind inundation canals. The Rau Commission examined the legal position of water rights on the Indus and its tributaries and laid down certain general principles which were accepted by the parties concerned. Among thse principles was the following statement of water rights:

> 'In the general interests of the entire community inhabiting dry arid territories, priority may usually have to be given to an earlier irrigation project over a later one: "priority of appropriation gives superiority of right" (Wyoming v. Colorado, 259 U.S. 419, 459, 470).'

1.19 The "Draft Agreement between the Punjab and Sind regarding the sharing of the waters of the Indus and five Punjab rivers" was drawn up by the Chief Engineers of the two provinces in 1945. The Draft Agreement deals with technical details of sharing river supplies and incorporates most of the recommendations and allocations of the 1935 Anderson Committee. It took account of the prior rights of old canals with established supplies and also made allowance for equitable apportionment to canals which were still new or projected in 1945. The Sind Punjab Draft Agreement had not been ratified before negotiations were terminated when Pakistan became independent in 1947. However, in spite of changing circumstances, the procedures based on the Draft Agreement which take account of various possible conditions of flow and also allow for a time lag between Punjab and

Sind, have in the past proved generally successful as a means of allocating natural river flows.

1.20 Apart from the aspects of the Draft Agreement which dealt with the procedures for sharing surpluses and deficiencies in the river flows, two other important features were:

- Withdrawals for any canal were given priority over withdrawals for storage (Clause 2).

- The method for determining the supplies to be given to inundation canals on conversion to weir control is basically that the supplies given should equal the average supplies taken in any ten year period prior to conversion (Clause 8).

1.21 The Indus Waters Treaty, concluded between the Governments of India and Pakistan through the good offices of the IBRD, took effect from the 1st April 1960. It provided for a transition period which ended on the 31st March 1970. The main provision regarding the Eastern Rivers, the Ravi, Beas and Sutlej, after the end of the transition period, was:

> 'All the waters of the Eastern Rivers shall be available for the unrestricted use of India, except as otherwise expressly provided in this Article' (Indus Waters Treaty 1960 Article II Para 1).

1.22 With some small exceptions, mainly in Kashmir, Pakistan is allowed full use of the Western rivers, the Indus, Jhelum and Chenab, from the 1st April 1960. The main provision in the treaty regarding the Western rivers was:

> 'Pakistan shall receive for unrestricted use all those waters of the western rivers which India is under obligation to let flow under the provisions of paragraph (2)' (Indus Waters Treaty 1960 Article III Para 1).

1.23 The exceptions referred to in Article II Para (1) and Article III Para (1) relate to domestic, nonconsumptive and limited agricultural uses. The total of all these uses is insignificant in comparison with flows in the rivers, and it is specially mentioned in the Treaty that nonconsumptive uses will not materially change the flow in any channel (Indus Waters Treaty 1960 Article IV Para (2)). The Treaty is concerned only with the division of river flows between India and Pakistan and not allocations between the various canal systems in Pakistan.

Method of Distributing Supplies

1.24 Up to the time that Mangla dam was commissioned in 1967 the method of distributing supplies related only to natural river flows. No allowance was made - or indeed still is made - for the availability of groundwater supplies. The introduction of Mangla reservoir storage into the existing system, essentially as a replacement for eastern river flows under the terms of the Indus Waters Treaty (1960), but also with a development element, necessitated the superimposition of an additional distribution pattern on to the procedures previously used.

1.25 Distributions on the Indus River itself are clearly stated in the Draft Agreement. Thal canal at Kalabagh Barrage, the canals at Sukkur Barrage and certain channels which used to receive supplies from old inundation systems, share the first priority and deliveries to the areas served by these canals are maintained at fairly consistent levels. The newer canals at Taunsa, Gudu and Kotri Barrages have relatively low priority and shortages on the Indus River tend to be concentrated in these areas which are mostly non-perennial.

1.26 First right to the natural flows of the Jhelum and Chenab Rivers is given equally to the Upper and Lower Jhelum Canals, the Upper and Lower Chenab Canals and Lower Bari Doab Canal. These canals, known collectively as 'five linked canals,' also receive some water from the Ravi River although, under the terms of the Indus Waters Treaty, such supplies are limited to flows which cannot be utilized in India. They supply the whole CCA of Chaj Doab, 95 percent of the CCA of Rechna Doab and 27 percent of the CCA of Bari Doab. Supplies to most of the area are perennial and, like the first priority Indus canals, are maintained at fairly consistent levels.

1.27 The canals on both sides of the Sutlej valley were, prior to the advent of Mangla and the IBP link canals, primarily dependent on the uncertain flows of the Sutlej River for their supplies. Priorities are technically equal between these canals, although within the commands the design generally favors perennial areas. River flows in the Sutlej valley have been inadequate since the construction of the canals there between 1926 and 1929 and this inadequacy was the most important of the factors which led to the abandonment in the early 1930's of large areas of the projected CCA.

1.28 Trimmu Barrage and Panjnad Barrage receive river supplies only after the first priorities for the five linked canals have been met in full. For this reason Rangpur, Haveli, Sidhnai in part, Abbasia and Panjnad Canals, which are served from these barrages, have in the past suffered from frequent shortages, particularly in the rabi cropping season. After certain minimum requirements have been satisfied at these barrages, Sukkur has priority for part of any surplus flows at Panjnad.

1.29 The Sind-Punjab Draft Agreement was rendered obsolescent by partition of the former Punjab at Independence in 1947, although this would not be of importance if the procedures for allocations contained therein were found to be the most efficient for existing and future conditions. There are a number of reasons for concluding that such is not the case:

- Firstly the storage projects envisaged in the Draft Agreement related to limited sites outside Pakistan (including Bakhra) and thus the procedures have little bearing on the mode of operation of Mangla, Chashma and Tarbela storages. As Mangla is essentially for replacement of eastern river flows, the operation and allocation problems are clearly less difficult than with storages on the Indus and, indeed, seem to have been successfully overcome during the period since commissioning in 1967. Chashma storage is only 0.68 M ac-ft and has been distributed on an ad hoc basis under the pressure of events since it became available in 1971. The major problem will clearly arise with the advent of Tarbela storage.

- Secondly the procedures as laid down relate only to natural river flows and make no allowance for the development of groundwater resources under the public tubewell programmes. Major studies of the Indus Basin have concluded that it is vital to optimum development in the longer term for groundwater supplies to be integrated with canal deliveries.

- Thirdly the IBP link canals which cross the Punjab from west to east were not envisaged in the Draft Agreement. Again, in so far as they form part of the replacement works of the Indus Waters Treaty the allocation problems do not seem too severe. The major difficulties arise with Indus Links system - the Chashma Jhelum and Taunsa Panjnad Links.

1.30 It is believed that a special commission was established in 1971/72 to devise a new distribution pattern, taking account of the changed circumstances outlined above. It is understandable that the issues involved are sensitive but nevertheless it seems essential that the water distribution problems should be resolved in order to enable the country to plan to realize maximum benefits from the major Tarbela project.

The Indus Special Study

1.31 In 1963, the then Presidents of Pakistan and of the World Bank reached an understanding that the Bank would organize a study of the water and power resources of Pakistan. The main objective of the study was to determine the optimum course of development in the fields of agriculture and power bearing in mind the water resources available to Pakistan after implementation of the Indus Waters Treaty of 1960.

1.32 In order to provide the expertise necessary to cover the complex and detailed field work involved in the study, a number of consulting firms were engaged. For irrigation and agriculture aspects three firms, Sir Alexander Gibb and Partners and Hunting Technical Services Ltd. of U.K. and International Land Development Consultants (ILACO) of the Netherlands, formed a group known as the Irrigation and Agriculture Consultants Association (IACA). Other firms were engaged to cover power aspects and surface water storage.

1.33 The final reports of IACA, which were submitted to the Bank in 1966, included a comprehensive analysis of all existing data on irrigation and agriculture to establish the base levels on which an action programme for future development could be assessed. The IACA reports formed the basis for irrigation and agriculture aspects of the Bank Study Group's own reports which were submitted to the President of Pakistan through the President of the Bank in 1967.

II. RECENT SURFACE WATER DEVELOPMENTS

River Inflows

2.01 At the time of the Indus Special Study IACA determined long term mean flows for the three Western Rivers, the Jhelum, Chenab and Indus, based on the period of record from 1922-23 to 1962-63. These data were used to establish a basis on which to judge additional surface water requirements for irrigation development in the basin. The kharif, rabi and annual inflows since the IACA studies are given in Table 1.1 for each year together with the IACA mean flows for comparison. The effect of Mangla regulation of the Jhelum since 1967 is also given.

2.02 The total rabi or dry season flows of the Western Rivers have been at or below the mean levels in six of the eight year since 1965 with particularly low years in 1970/71 and 1971/72. In these two years even the addition of Mangla storage releases failed to raise the total flows to mean levels. Conversely the kharif season flows during the same period have been at or above mean levels with the exception of 1970 and 1971 and to a lesser extent 1972.

2.03 With this generally unfavorable period of inflow since Mangla was introduced to system in 1967, it is fortunate that India was unable, either by virtue of the terms of the Indus Waters Treaty, or because of the pace of development in India, to withdraw all rabi supplies in the Eastern Rivers. As will be noted from Table 1.2 flows in the Eastern Rivers continued at significant levels, though reductions are inevitable.

Canal Head Withdrawals

2.04 The withdrawals for each canal system in Pakistan are shown in Tables 1.3, 1.4 and 1.5 for the rabi and kharif seasons and annually for the hydrological years 1965 through 1973. The mean level of withdrawals for the preceding 11 year period is also shown for comparison. This latter period is similar to, but advanced by 2 years, from the 1952-1963 period used as the basis of IACA projections.

2.05 Kharif withdrawals have generally been maintained at or above the previous mean levels for the years since 1965 apart from the areas fed by the Jhelum and Chenab rivers during the particularly low inflow years of 1970 and 1971. The Indus commands have shown significant increases compared to the previous levels, particularly the Lower Indus region, reflecting the continued development of the commands in these areas. For the rabi season the canal head withdrawals since 1965 in Lower Indus have also shown significant increases although for Pakistan as a whole withdrawals have varied around the previous mean levels depending on the river inflow conditions. The increases in rabi season withdrawals in the Lower Indus canals had largely resulted from a reduction in the escapages below Kotri Barrage at the tail of the system. These escapages were at significant levels during the period taken by IACA to establish mean withdrawals as is demonstrated in Table 1.10. The mean rabi escapage during the 11-year period used by IACA was nearly 12 M ac-ft whereas in the ensuring 10 years it has been less than 2 M ac-ft. Against this the contribution of flows from the Jhelum/Chenab zone below Panjnad has reduced considerably over the same period from 4.5 M ac-ft to about 0.5 M ac-ft leaving a net average gain to the canal systems of about 6 M ac-ft.

The Impact of Mangla Reservoir

2.06 Impounding of the major Mangla reservoir, with a live storage of over 5.3 Mac-ft; commenced in early 1967 and the first full hydrological year of operation was 1967/68. Operation of the reservoir has since that time been controlled by the Water and Power Development Authority (WAPDA) through the Mangla Dam Organization (MDO).

2.07 For each season the WAPDA Water Management Cell (WMC) evolve "suggested criteria" for operation of the reservoir to optimize the water and power benefits of the project in the light of:

(i) likely availability of natural run-off in both the Western and Eastern Rivers;

(ii) maximum possible irrigation uses which can be provided by the existing facilities;

(iii) effective regulation of Jhelum flows by Mangla storage in conjunction with the river integration facilities provided by the Indus Basin Project (IBP) works; and

(iv) effects of the suggested mode of operation on energy generation at Mangla.

The "Suggested Criteria" are evolved from a series of alternative water studies on the operation of the irrigation system dependent on Mangla which are carried out by WMC using the computing facilities available to WAPDA in Lahore.

2.08 The actual operation of the reservoir by MDO is based on:

(i) the "Suggested Criteria" of WMC;

(ii) the indent of the Provincial Irrigation and Power Department (IPD); and

(iii) the power demands as intimated by the WAPDA Power Controller.

2.09 As Mangla is primarily an irrigation project for replacement of Eastern River flows, the indent of the IPD is normally met in full. In the event of conflicting irrigation and power demands or operational difficulties the matter is resolved at high level discussions between IPD and WAPDA. In point of fact such conflicts have occurred only occasionally since Mangla was commissioned for the following reasons:

(i) for the first 18 months of operation the IBP Link system, designed to feed the areas previously served by the Eastern Rivers, was incomplete;

(ii) delays in completing the transmission link between Mangla and the main load centers; and

(iii) the full capacity of the Mangla Power Station had not been reached. Up to January 1974 only 400 MW out of the eventual capacity of 800 MW was in operation (Units 1-4). Units 5 and 6 were commissioned early in 1974.

2.10 The operation of Mangla reservoir since it was commissioned in 1967 is illustrated in Table 1.6, which shows the fluctuation in gross reservoir content and the net regulation effect on Jhelum flows. The table clearly indicates that significant use has been made of the storage to increase flows at the time of rabi planting in October and November of each year, which has contributed towards a considerable expansion of wheat acreage in the Punjab. Since the average yield and total production of wheat have also increased appreciably it is clear that the timely nature of canal deliveries has more than compensated for the lower than average rabi withdrawals in the Jhelum/Chenab zone discussed earlier in this chapter.

2.11 The overall effect of Mangla on rabi river supplies is indicated below for the years 1967/68 to 1972/73.

Rabi River Inflows as % of IACA Mean

	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73
Jhelum without Mangla Regulation	116	112	87	64	71	154
Jhelum with Mangla Regulation	185	179	188	163	137	221
Jhelum and Chenab without Mangla Regulation	118	98	75	64	71	134
Jhelum and Chenab with Mangla Regulation	155	133	128	116	105	169
Jhelum, Chenab and Indus without Mangla Regulation	106	97	87	75	77	113
Jhelum, Chenab and Indus with Mangla Regulation	120	111	108	95	91	127

Relative to the IACA base the increase in rabi flows in the Jhelum alone was between 65 and 70% for four of the six years of operation whilst the increase in combined flows for the same years was around 35% for the Jhelum and Chenab and 14% for the Jhelum, Chenab and Indus. In these years a significant amount of the live storage remained unused at the end of the rabi season whereas, in the other two years, 1969/70 and 1970/71, the reservoir was effectively emptied and the resultant increases in flows relative to IACA levels were much greater - 100%, 50% and 20%, respectively. The seasonal use of Mangla storage since commissioning is given in Table 1.11 which clearly supports the points made above.

2.12 From a comparison of rabi river supplies and canal withdrawals it would appear that the net effect of Mangla storage releases in increasing overall water availability has not been as great as might have been imagined. This must have been occasioned by the regulating effect of Mangla reservoir on flood discharges which has reduced bank storage in the kharif season with a consequent reduction in the amount of regeneration in the rabi season of the order of 2 M ac-ft, as can be seen from an examination of the pre and post Mangla gains/losses in Table 1.10.

Operation of Chasma Storage

2.13 The initial impounding of Chasma Barrage storage took place in the kharif season of 1971. The gross reservoir content was originally estimated as 0.88 M ac-ft with a live storage of 0.8 M ac-ft but a recent hydrographic survey has indicated that substantial silting has already taken place in certain parts of the reservoir reducing the storage to 0.76 M ac-ft gross, 0.68 M ac-ft live.

2.14 Operation of the Chasma storage is carried out in the light of "Suggested Criteria" developed by the WMC. The allocation of Chasma storage up to the present has been on the basis of so-called ad-hoc arrangements set by the Central Government which stipulate sharing on a 50-50 basis between Punjab and Sind after meeting the normal requirements of 0.1 M ac-ft for the Paharpur Canal of NWFP which offtakes from the Chasma Barrage.

2.15 The fluctuations in gross reservoir content and storage releases to Punjab, Sind and NWFP are shown in Table 1.7 for the period since the reservoir was impounded. It will be noted that the Paharpur Canal has not taken its full allocation, due, it is understood, to lack of demand. The outstanding amount appears to have been reallocated to the Punjab via C-J Link. Also, although Sind took its full allocation in 1971/72, about 0.13 M ac-ft remained unused in the reservoir at the end of the 1972/73 rabi season, and this storage was reallocated partly to Sind and partly to Punjab in the ensuing month.

The Link Canals

2.16 Apart from Mangla Dam, the other major works arising out of the Indus Waters Treaty were three systems of link canals to transfer water from the Western Rivers to the areas formerly fed from the Eastern Rivers. Two of the systems of links, the Rasul-Qadirabad-Balloki-Suleimanki (RQBS) system and the Trimmu-Sidhnai-Mailsi-Bahawal (TSMB) system connect the Jhelum river through to the Sutlej whilst the third system - the Indus Links system consisting of two separate links, the Chasma-Jhelum and the Taunsa-Panjnad - connects the Indus with the Jhelum and the Chenab.

2.17 Link Canals Prior to IBP. Three other link canals built by Pakistan after Partition but prior to the Indus Waters Treaty were intended to alleviate some of the problems arising from the dispute over the Eastern Rivers waters. These canals are:

- the Marala-Ravi (MR) Link from the Chenab to the Ravi River, which was commissioned in 1956 with a head capacity of 22,000 cusecs. Extensive silting in the head reaches has reduced its capacity to about 14,000 cusecs.

- the BRBD Link which feeds the Dipalpur above BS Link canal and the Pakistani areas of the former Central Bari Doab canal from Chenab supplies through an offtake on the Upper Chenab Canal and a cross link from the MR Link. The BRBD link, which was commissioned in 1954, can supply a total of nearly 5,000 cusecs to the two command areas.

- the Balloki Suleimanke I (BS I) Link which supplies the Dipalpur Below BS Link canal and the canals off-taking from Suleimanke Barrage. This link was originally commissioned in 1957 with a designed capacity of 15,000 cusecs, which was never achieved. The head reach was remodelled to carry 18,500 cusecs as part of the Indus Basin Project (IBP) works.

Together with the much older Upper Jhelum and Upper Chenab canals, which also have transfer functions, these links formed the transfer system as it existed prior to construction of the IBP works.

2.18 The TSMB System. The first IBP link system to be commissioned was the TSMB which began operation in March 1965. The TS link which has a capacity of 11,000 cusecs transfers water from the Jhelum at Trimmu Barrage to the Ravi above Sidhnai Barrage. The SM Link carries 10,100 cusecs to feed the lower areas of the Pakpattan and Mailsi canals and also passes 4,000 cusecs through the MB Link to feed the lower areas of the Bahawal canal. The TSMB system is commandable by all the Western rivers including the Indus through the C J Link.

2.19 The RQBS System. The other major cross-Punjab link system, the RQBS, was fully commissioned in mid 1968 although the QB element had been operable a year earlier. The RQ link, with a capacity of 19,000 cusecs transfers to the Chenab above, Qadirabad Barrage. The QB link transfers 14,500 cusecs to the Ravi above Balloki where the BS canals supply the Sutlej above Suleimanki and the Dipalpur below BS Link canal. The remodelled BSI link head reach has a capacity of 18,500 cusecs but bifurcates into the BSI (12,000 cusecs) and the newer BSII (6,500 cusecs). The RQBS system has a vital role in transferring Mangla stored water to the areas previously fed from the Eastern Rivers but is not commanded by the Indus River.

2.20 The Indus Links. The largest of the IBP link canals is the C J link which was commissioned in 1971 with a capacity of 21,700 cusecs. The C J Link carries Indus supplies to the Jhelum above Trimmu Barrage and the TSMB system. Lower down the Thal doab the T P Link, commissioned in 1970 with a capacity of 12,000 cusecs, also connects the Indus with the Chenab and outfalls above the confluence of the Chenab and the Sutlej to serve the Panjnad Barrage commands.

2.21 The IBP links give great flexibility in operation of the overall canal system in the Punjab. Apart from the primary purpose of direct replacement the use of Jhelum water (including Mangla) in the areas fed by the RQBS system allows Chenab and such Eastern River flows as are available to be used further north. The philosophy of substitution applies even more in the areas fed by the TSMB system which can be supplied with Indus water from the C J Link and also in the Panjnad commands which can be served from TP Link. However the full extent of substitution of supplies and integrated operation cannot become a reality before Indus storage at Tarbela is available in 1975/76 since, until that time, apart from the limited storage at

Chasma, the rabi flows in the Indus are essentially committed to areas fed from the Kalabagh and Taunsa barrages and to the lower Indus areas in Sind.

Use of IBP Link Canals

2.22 An analysis of the utilization of the IBP link canals since Mangla was commissioned in 1967 is given in Table 1.8. The maximum 10 day average flows and total seasonal flows are given for each link to indicate the extent to which full capacity has been used and the total water transferred respectively.

2.23 All the link canals have been operated at or very close to their design capacity during the period; indeed the TSMB system has regularly run at 5 to 10% over capacity in the kharif season. Total seasonal transfers have generally been higher in kharif than rabi as might be expected - apart from RQ link due presumably to withdrawals for Mangla storage. Apart from 1967/68 when the RQBS system was not completed and 1972/73 when the natural flows in the Jhelum were over 50% above mean levels, the rabi flows in the TSMB system have not been particularly high. The main transfer of Mangla storage to the Eastern River areas has logically been through the RQBS system in order to give greater flexibility of distribution. However, apart from the high flow year of 1972/73 the total combined rabi transfers of the RQBS and TSMB systems has been less than the storage releases from Mangla by as much as 2.5 M ac-ft. Since the rabi withdrawals on the Jhelum fed canals have generally been at less than mean levels this tends to confirm the point made earlier in para 2.12 that the increase in water availability in rabi on account of Mangla storage has to some extent been offset by the reduction in regeneration from bank storage. The relationship between rabi Mangla storage releases and IBP link canal transfers is shown in the tabulation below.

Relationships between Rabi Mangla Storage Withdrawals and IBP Link Canal Transfers

(M ac-ft)

	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73
Mangla Rabi Storage Releases	3.92	3.68	4.75	4.60	3.34	3.86
TSMB Rabi Withdrawals	1.36	0.14	0.59	0.25	0.12	1.06
RQBS Rabi Withdrawals	-	3.62	3.69	3.81	3.09	6.36
Storage Not transferred	2.56	0.06	1.06	0.79	0.25	-2.50

2.24 The Indus Links system, C J and TP Links, have been operation for a much shorter period and there have been only nominal rabi transfers as will be seen from Table 1.8, and this situation will continue until Tarbela storage becomes available. No evidence of the accumulation of wind blown sand in the prisms of the Indus links has been given but this potential problem was the cause of some concern in the past, particularly in regard to the desert areas through which the C J Link passes.

III. TARBELA DAM AND WATER DISTRIBUTION ISSUES

The Tarbela Project

3.01 The major Tarbela dam on the Indus has been under construction since 1968. The project civil works consist of a main embankment structure 450 feet high above the foundation level, two auxiliary embankment dams 345 feet and 220 feet high respectively (together the three dams contain of the order of 200 million cubic yards of fill material) auxiliary and service spillways with a combined discharge capacity of nearly 1.5 million cusecs together with a total of six irrigation and/or power tunnels. On the right bank three of the four main tunnels are ultimately intended for power uses although Tunnel No. 3 will initially be used for irrigation releases in conjunction with Tunnel No. 4. Only a short section of the remaining tunnel on the right bank is being constructed under the present contract since it is intended for future irrigation development in the right bank areas downstream of the dam (Pehur High Level Canal Project). On the left bank a further irrigation tunnel is provided which can pass nearly 100,000 cusecs down the river with the reservoir at its normal maximum retention level.

3.02 Ultimately 12 turbo-generator units will be installed at Tarbela, each of 175 MW capacity, although the initial installation will only be four units to be fed through Tunnel No. 1.

3.03 The reservoir retained behind Tarbela dam will have a gross capacity of 11.1 M ac-ft up to the normal maximum retention level of El 1550 ft. With dead storage of 1.8 M ac-ft below the assumed lowest drawdown level of El 1300 ft. the reservoir will provide a live storage of 9.3 M ac-ft for the combined use of power and irrigation.

Present Status of the Tarbela Works

3.04 Despite technical problems with gravels in the river bed which have necessitated a considerable extension of the upstream blanket areas, impounding of the reservoir commenced on 1 July 1974. Subsequent problems with the irrigation and power tunnels necessitated the release of all stored water to effect repairs.

3.05 It is expected that after the first turbo-generator unit is ready for commissioning, Units 2, 3 and 4 would follow at short intervals, giving a total initial installed capacity of 700 MW. There are no firm plans for Units 5 to 8 although WAPDA's recent "Power Development Programme for the Fifth Plans" published in February 1974 indicates that Units 5 and 6 should be commissioned in March 1978 with Units 7 and 8 following one year later. This programme cannot be achieved unless the associated civil engineering works are carried out by the present Tarbela Contractor (TJV) and even under these circumstances is probably optimistic.

3.06 Providing no further unforeseen difficulties arise, the full Tarbela live storage of 9.3 M ac-ft should be available for use in the 1976/77 rabi season. However, there may be constraints on operation of the reservoir associated with testing and commissioning the first four power units.

The Distribution of Tarbela Water

3.07 At the time that the viability of the Tarbela Project was under review IACA conducted a series of water use studies for the basin to ascertain the possible distribution of Tarbela storage water through time. These studies were in no way constrained by provincial considerations since at that time Pakistan (or West Pakistan as it then was) had been formed into a single administrative unit. The studies were based on crop water requirements established from cropping patterns and production levels for each area related to the projected demand for agricultural produce through time and the "Action Programme for Development" assumed.

3.08 Table 1.9 indicates the results of these earlier studies for the year 1975 when it was assumed Tarbela storage would become available. Total requirements derived at that time at the watercourse will no longer be valid under present circumstances in view of the considerable shortfall in the complementary development programme, changes in the agricultural situation as a result of new seed varieties (principally of wheat in the context of rabi water usage) and also the very considerable development of private tubewells, mainly in the Bari and Rechna Doab areas of the Punjab. To assess the use of Tarbela storage under present circumstances would require a revision of the analysis used by IACA. At the time of the IACA studies it was assumed that watertable control would essentially have been achieved prior to commissioning of Tarbela and thus the possibility of waterlogging and its associated effects was not a major consideration in defining the areas to which Tarbela storage could be supplied.

3.09 It should be recognized that, apart from the areas fed by canals with a severe capacity constraint, the provision of vertical drainage in fresh groundwater areas will generally provide most of the incremental water supply necessary both in terms of volume and timing to achieve the assumed ultimate cropping intensity. The major demand for additional rabi surface supplies should probably be in the saline groundwater areas (which are generally the perennial areas in any case), but the full extent of this demand would not arise without significant remodelling of the canal systems and watertable control by appropriate methods. Also since the head reaches of most of the main canals pass through fresh groundwater areas, with higher watertable areas near the river line sources of recharge, the effects of additional seepage losses in these areas arising from the passage of incremental supplies to the saline groundwater areas further down the system must be taken into consideration.

3.10 The advent of the so-called "Green Revolution" and the remarkable increase in the overall production levels of foodgrains in Pakistan arising from the introduction of the new varieties of rice and wheat has had a significant impact both on the cropping patterns necessary to sustain the projected demand for foodgrains and also on the volume and timing of rabi irrigation requirements.

3.11 The considerable increase in the number of private tubewells operating in the Punjab canal command areas since ISS has, at least in part, been due to the shortfall in the public tubewell projects which were to be complementary to the Tarbela Project. There is no doubt that the output of private tubewells has had a considerable impact on overall agricultural production in the Punjab, particularly in ensuring the timely supplies of irrigation water necessary to achieve maximum yield from the new crop varieties. From the drainage and irrigation viewpoints, however, there is a certain lack of operational flexibility inherent in private tubewell development since control is vested solely in the owner of the well. From cost considerations, a farmer will always take such surface supplies as are available rather than use his well. Operation of the private tubewell results in a direct charge to the farmer proportional to the quantity of water produced whereas payment for surface supplies is related to the area cropped rather than the volume supplied. Thus the provision of additional rabi surface supplies from Tarbela storage to areas with significant private tubewell development is unlikely to result in a proportional increase in the amount of irrigation water applied to the crops.

3.12 Present efforts to reach agreement on the distribution of Tarbela storage supplies appear to have been based on provincial demands which are likely to be formed on historical precedents rather than related to the optimum use of such supplies. Whilst recognizing the importance of interprovincial viewpoints, it would be unfortunate if any agreement on the distribution of Tarbela water would only be based on these considerations. It is essential that flexibility should be retained in order to re-adjust priorities for Tarbela supplies as the complementary drainage and remodeling development proceeds. Thus use of Tarbela supplies is likely to change through time and a distribution agreement should recognize this fact.

3.13 In Table 1.9, the status of canal commands in relation to absorption of Tarbela storage is given together with an assessment of the possibility of using additional rabi surface supplies in each command in relation to the existing watertable conditions and the potential drainage problems which could arise. Without a detailed review of the operation of each canal command taking account of all the related parameters, it is not possible to quantify the amount of storage that can be safely absorbed at the present time or the likely time scale of any detrimental effects that might occur. Due to the provincial arguments put forward for the allocation of supplies it is almost certain that a significant amount if not all of Tarbela storage will be released in the rabi season in the early years of operation which perhaps emphasizes the need for some guidance for the Pakistan authorities on the technical aspects of the allocation problem, particularly if the irrigation benefits previously ascribed to the Tarbela Project are to be realized.

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PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

TECHNICAL NOTE NO. 2

SOILS AND GROUNDWATER

INDEX

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SOILS AND GROUNDWATER

I. SOIL SURVEY INFORMATION

Availability of Base Maps [1/]

1.01 Aerial photographs of the entire country were obtained in 1953; enlargements from the negatives are still used for most soil survey work. Topographic maps at a scale 1:50,000 with 20 foot contours, and 1:250,000 with 250 foot contours are available for all of Pakistan. All topographic maps are made from aerial photographs; however, often not as rapidly as desired. WAPDA now maintains 4 or 5 surveys crews for making detailed surveys on canal lines, dam locations, and other detailed investigations and so the availability of topographic maps is not a serious constraint to its planning.

1.02 Foreign experts in the fields of photogrammetry, surveying and printing are being sought to train staff members of a proposed quasi-governmental corporation that would produce aerial, topographic and other maps needed for local development work and the World Bank may be asked to assist in filling these positions.

Soil Surveys

1.03 Surveys by Soil Survey of Pakistan - Between 1961 and 1970 a cooperative Soil Survey Project was carried out by the Government of Pakistan, the United Nations Development Program (UNDP - SP) and the Food and Agricultural Organization of the United Nations (FAO). The survey coverage was largely confined to the irrigated and dry-farmed areas, and the survey results of 23 areas are presented in the reports listed below. By 1972 about 90,000 of the 120,000 square miles of potential agricultural land had been covered by the Soil Survey of Pakistan. These soil surveys are reconnaissance type and of very limited use for project appraisal and not sufficiently detailed for studies of land reclamation or drainage. Air photos at a scale of 1:40,000 are used as base maps. Soils are examined on parallel traverses 1 to 2 km apart with frequency of observation along the traverses from 50 meters to 1 kilometer depending on soil variability. Generally pits were dug to a depth of 20 inches followed by augering to a depth of only 48 inches. Texture, color,

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1/ Mostly from S.Q. Hasan, Surveyor-General of Pakistan.

structure, porosity, lime content, slope, and pH were noted. An average of only one sample per 100 sq. miles was taken to a laboratory for detailed analyses. The mapping units showing soil associations are transferred to topographic maps at a scale of 1:50,000 and the resulting maps reduced to a scale of 1:125,000 by means of a pantograph.

Areas Surveyed by Soil Survey of Pakistan

Reconnaissance Soil Survey Report	Sq. Miles	Million Acres	Report Issued
Peshawar Vale	3,440	2.20	1967
Lyallpur	3,420	2.19	1967
Rawalpindi	3,642	2.33	1967
Gujrat	2,264	1.44	1968
Gujranwala and Sialkot	4,379	2.80	1967
Sheikhupura	2,381	1.52	1968
Lahore	2,216	1.41	1968
Jhang	3,236	2.07	1968
Sahiwal	4,224	1.70	1968
Thal North	6,143	3.93	1969
Thal South	3,822	2.44	1969
Thatta East	3,388	2.17	1969
Sargodha, 2nd Ed.	2,290	1.47	1969
Multan South	2,885	1.85	1970
Multan North	2,703	1.73	1970
D.I. Khan	3,601	2.30	1970
Jacobabad	2,298	1.47	1970
Ghotki	2,326	1.49	1970
Muzaffargarh	1,614	1.03	1971
Khairpur	2,119	1.36	1971
Hyderabad	1,624	1.03	1971
Badin	3,480	2.23	1971
Campbellpur	4,130	2.64	1971

1.04 Soil Surveys by WASID and WAPDA. The soil survey work conducted by WASID (formerly part of WAPDA) is oriented toward soil-water relationships and drainage and accordingly is useful in appraisal of projects. They use a modification of the U.S. Bureau of Reclamation land classification procedure. Work is done on aerial photos at a scale of 1:15,840. Five borings to 10 foot depth are made in each square mile and the soil is sampled at depths 0-6", 6-18", 18-36", 36-72", and 72-120" for laboratory studies. Laboratory data include salinity (EC X 10^3 of saturation extract), pH, sodium adsorption ratio (SAR), cation exchange capacity (CEC) and exchangeable sodium percentage (ESP). The land is delineated primarily by the texture of the subsoil, secondarily by the texture of the surface, and when necessary by the texture of the substratum.

1.05 All of the Punjab and a portion of North West Frontier Province have been covered by the WAPDA type soil surveys. Unfortunately, since the bulk of the work was done in the early 1960's, the results may be obsolete with respect to present salinity and alkali conditions. A summary of the results of WAPDA soil surveys for Punjab Province follows:

Soil Groups in Punjab

(Values in 1000's of Acres)

Soils Group	Predominant Texture	Thal Doab	Chaj Doab	Rechna Doab	Bari Doab	Bahawalpur Plain	Total
Jhung	Loamy Sand	1,232	317	785	555	575	3,464
Farida	Sandy Loam	1,550	682	2,295	1,110	1,237	6,874
Buchiana	Silt Loam	517	901	1,872	4,509	1,561	9,360
Chuharkana	Light Clay	159	439	906	486	411	2,401
Nokhar	Heavy Clays	0	24	20	0	0	44
Unclassified	Mixed	517	73	121	278	288	1,277
Total		3,975	2,436	5,999	6,938	4,072	23,420

1.06 In recent years WAPDA has de-emphasized soil surveys and at this time there are only 4 or 5 soil scientists available for this work. Conversely the work of the Soil Survey of Pakistan has increased to 18 Survey Officers and 54 Survey Assistants. This organization has the technical capability to produce soil surveys that include soil-water and other relationships and it would seem advisable to include these two soil survey organizations into a single group oriented to produce surveys useful for drainage and land reclamation as well as other purposes.

1.07 Soil Surveys by Hunting in Sind. WAPDA made no soil surveys in Sind apparently because Hunting Technical Services Ltd was doing somewhat similar soil survey work in the Province, although only of a reconnaissance nature, in the course of their project investigations. Hunting's surveys also need updating with respect to salinity, alkali and water table conditions. A summary of soil distribution by type of deposition according to Hunting is as follows:

Suitability of Sind Soils for Irrigation by Origin
(in Percent)

Type	Origin	Irrigation Suitability by Soil Class 1	2	3	4	5
Meander Flood Plain	58	37	12	6	2	1
Cover Flood Plain						
- (shallow)	9	5	2	1	1	-
- (deep)	21	16	2	2	1	-
Bar Deposits	10	7	2	1	-	-
Levees	2	1	-	-	1	-
Total	100	66	18	10	5	1

There is not a good correlation between soil classes, as developed by Hunting, and crop yields except in the case of the abandoned and never cultivated lands, as shown below:

Crop Response and Soil Classes in Sind

Crop Conditions	No. of Sites	Soil Class - in Percent				
		1	2	3	4	5
Good	73	40	40	17.5	2.5	-
Poor	152	38	31	16.5	12.5	2
Failure	38	39.5	37	10.5	8.0	5
Fallow	219	42	33	18.0	6.0	1
Abandoned	147	6	15	13.5	35.5	30
Never cultivated	110	6	12	13.0	25.5	43.5

II. SALINITY

2.01 Government of Pakistan estimates that the effects of salinity and water-logging causes losses to the economy of at least $250 million a year, not including loss of tax revenues associated with these problems. Restricted drainage is the most common cause of excessive soil salinity. However, salinity can develop in the absence of irrigation if the water table is within about 10 foot of the soil surface, or where so little irrigation water is applied that leaching does not occur. Where the annual rainfall is about 10 inches or more (250 mm) excess salinity probably would not develop because of insufficient irrigation except in soils of extremely low permeability.

2.02 Sind - Saline soils occur throughout the country but particularly in Sind Province where, owing to the lower rainfall and finer soil textures, 50 to 75% or more of the 13.2 million acres of culturable commanded area (CCA) is excessively saline and 36% is sufficiently saline to prevent economic crop production. According to WAPDA salinity conditions in the Sind are as follows:

Salinity Conditions in Sind

Area	CCA	Moderately Saline		Highly Saline		Saline-Alkali		Total Salt-Affected	
	M ac	M ac	%	M ac	%	M ac	%	M ac	%
Gudu Barrage (R. Bank)	1.97	0.47	24	0.37	19	0.67	34	1.52	77
Gudu Barrage (L. Bank)	0.84	0.11	13	0.06	7	0.16	19	0.33	39
Sukkur Barrage (R. Bank)	1.97	0.41	21	0.43	22	0.83	42	1.68	85
Khairpur	0.64	0.18	28	0.14	22	0.09	14	0.47	74
Nara	2.24	0.49	22	0.38	17	0.69	31	1.57	70
Ghulam Mohammed (Kotri)	2.92	0.38	13	0.47	16	1.78	61	2.63	90
Rohri	2.61	0.52	20	0.10	4	0.65	25	1.28	49
	13.19	2.56		1.95		4.87		9.48	

2.03 Hunting Technical Services Ltd. more or less confirms WAPDA's figures and finds the salinity status in Sind to be the following:

Percentage of Area Salinized in Sind

Description	Salinity Level (RC x 10^3)	Percent of CCA affected: Kotri	Larkana	Sukkur & Gudu
Slight to non-saline	0- 8	6.2	29.1	16.3
Moderate	8-15	14.8	28.6	23.0
Saline	15-40	14.4	16.6	21.0
Ultra saline	40	25.5	14.6	27.3
Complexes	0-40	31.2	10.9	12.4

It is not known positively how bad waterlogging and salinity are in the Sind but the mission was told that 20,000 acres are going out of production each year due to excess salinity alone.

2.04 Punjab - Soil salinity is not as much of a problem in the Punjab as in the Sind. About 25% of the Punjab soils are salt affected to some extent. The table on page 6 shows the percentages of the soils of the Districts of the Punjab that are sufficiently saline to virtually prevent crop production as well as the change in highly saline areas since 1968-69. The table on page 7 compares the changes in severe soil salinity from 1958-59 to 1971-72 for somewhat different districts and areas within districts. The data in both tables indicate that between 1958 and 1968 about 40,000 ac per year went out of production in Punjab, but that soil salinity is essentially in a static condition at present.

Highly Saline Areas in the Punjab /a

District	Total Acreage	Scarp(s) Involved	Percent of Area Affected 1968-69	1971-72
Gujrat	553,963	II	7.8	6.1
Sargodha	1,718,903	II	11.9	11.2
Lyallpur	2,147,675	I & IV	15.5	15.3
Gujranwala	1,131,136	I & IV	18.2	17.3
Sheikhupura	1,289,257	I & IV	28.4	24.0
Jhang	1,140,624	I & IV	24.4	21.6
Multan	3,038,996	-	15.3	14.6
Sahiwal	2,385,310	-	12.3	11.8
Muzaffargarh	1,717,731	III	17.8	10.9
D.G. Khan	805,929	-	14.7	13.1
Mianwali	916,143	-	0.8	0.3
Jhelum	2,423	-	25.8	25.8
Lahore	961,388	-	11.9	14.0
Sialkot	13,232	IV	5.9	5.5
Rahimyar Khan	1,585,470	-	16.3	16.2
Bahawalpur	1,025,958	-	5.6	6.1
Bahawal - Nagar	1,611,874	-	6.9	7.0
Total Punjab	22,046,012 /b		14.4 (3.2 M ac)	13.6 (3.0 M ac)

/a Data developed from visual survey carried out by the Directorate of Land Reclamation, Irrigation and Power Department, Punjab.

/b Total area of this survey. Actual gross acreage is close to 33.5 million acres, and total irrigated is about 23 million.

Salinity Changes in Punjab 1958-59 to 1971-72 /a

District or Division	Cultivable Area, M ac	Cultivated Area, M ac	Percentage of Area Highly Saline /b 1958-59	Percentage of Area Highly Saline /b 1971-72
Attock	1.34	1.14	0	0
Jhelum	0.90	0.73	7.3	25.8
Mianwali	2.65	1.41	0.2	0.3
Muzaffargarh	2.92	0.86	25.0	10.9
Rawalpindi	0.70	0.58	0	0
Gujranwala	1.29	0.95	80.6	17.3
Jhang	1.92	1.18	25.4	21.6
Lyallpur	2.05	1.77	10.4	15.3
Sheikhapura	1.34	0.94	52.8	24.0
Sialkot	1.12	1.06	0.4	5.5
Gujrat	1.20	1.05	5.0	6.1
Shahpur (Sargodha)	2.56	1.90	6.2	11.2
Lahore	1.15	0.97	9.8	14.0
Montgomery (Sahiwal)	2.42	1.97	9.9	11.8
Multan	3.26	2.42	12.6	14.6
D.G. Khan	2.42	1.06	0	13.1
Bahawalpur	0.93	0.70	( )	6.1
Bahawalnagar	1.44	1.13	(16.9)	7.0
Rahimyar Khan	1.48	1.13	( )	16.2
Punjab Totals	33.09	22.95	12.7 (2.9 M ac)	13.6 (3.1 M ac)

/a The 1958-59 data were developed from "Presidents Science Advisory Committee Report on Waterlogging and Salinity in West Pakistan", 1962. The 1971-72 data were developed by Directorate of Land Reclamation, Irrigation and Power Department, Punjab.

/b The 1958-59 totals include waterlogged as well as saline. If corrected for this, the total would be approximately 12.0%.

2.05 NWFP - There apparently was no severe soil salinity in the Northwest Frontier in 1958-59. Most of the D.I. Khan area is now salinized; the exact acreage is not known but it is substantial. Similarly, considerable areas are now severely salt-affected in the Vale of Peshawar.

III. ALKALI (SODIC) SOIL PROBLEMS

3.01 Sodic, or alkali, soils by definition have an exchangeable sodium percentage greater than 15. The pH is always greater than 8.5 and often greater than 9.0. The exchangeable sodium tends to cause dispersion of the clay fraction and this results in very low infiltration rates. Saline-alkali soils are high in both exchangeable sodium and salinity; the pH is less than 8.5, the ESP exceeds 15 and the ECe exceeds reasonable levels; before leaching they generally resemble saline soils and after some leaching they resemble sodic soils.

3.02 Sodium is the dominate cation in most of the groundwater in the upper Indus plains. Where sodium salts concentrate in the upper soil horizons, either through capillary action or by irrigation in amounts insufficient to permit adequate leaching, the soils may become high in exchangeable sodium (alkali or sodic). Where the anions are mainly bicarbonate, as in the plains of the eastern Indus tributaries, calcium precipitation may accelerate the development of excessive alkali (sodicity). Sodic soils are characterized by very low permeability, severe crusting, and excessive pH. Fortunately, the exchange complex commonly found in Pakistan is illitic (i.e. non-expanding) and thus much less sensitive to (i.e. can tolerate more) exchangeable sodium than soils of the Western United States, for example. As judged by the standards used in the United States, there are about 6.6 million acres of sodic soils in Pakistan, with the major portion in the Punjab (see tables, para 3.03 and 4). Sodic soils may range from those having a thin crust of sodium-affected material to a soil with a foot or more affected; thus the actual severity of the problem is less than indicated by tables, para 3.03 and 4. Based on limited data it appears that no more than half this total, even by definition, has sodic conditions below 2 inches. A survey to establish more precisely the extent and severity of sodic problem is necessary to establish the need for reclamation, particularly where use of gypsum is indicated.

3.03 The Central Monitoring Organization estimates that by definition about 400,000 acres of sodic soils exist in SCARP I and 17,000 acres in the Mona Project, and states that these have originated largely from the groundwater being used for irrigation. As stated above, there are about 6.6 million acres of sodic soils in Pakistan. Of these, about 10% are gypsiferous and perhaps 50% are only marginal problems. Thus, except for an aggregate area of possibly 500,000 acres, whose problems may be directly related to irrigation water quality (which may need to be altered by gypsum additions or mixing), the bulk of the 6.6 million acres are associated with high water tables and need little treatment other than leaching, whereas the remainder may require moderate to large amounts of gypsum for reclamation.

Saline - Sodic Areas in Punjab /a
Acres

Area or District	Acres of Saline-Sodic Soils	Acres of gypsiferous Saline-Sodic Soils
Lahore district	104,900	-
Sheikhupura area	709,100	-
Gujranwala - Sialkot district	273,300	-
Gujrat district	3,800	-
Sargodha	227,200	-
Lyallpur area	209,900	-
Thal North	9,300	-
Thal South	90,200	-
Jhang area	186,300	-
Multan North	538,200	9,600
Multan South	413,400	20,500
Sahiwal	430,700	-
Muzaffargarh	131,800	7,000
Bahawalpur	624,000	7,000
Bahawalnagar	302,700	-
Rahimyar Khan	408,300	62,000
Totals for Punjab	4,663,100	106,100

/a From Reconnaissance Soil Survey Reports of various districts of Pakistan, Directorate of Soil Survey Lahore, Pakistan, as compiled by Dr. S. Muhammed, University of Agriculture, Lyallpur.

Saline and Saline Sodic Soils in Sind /a
Acres

Name of Area or District	Strongly Saline	Saline-Sodic	Gypsiferous Saline-Sodic	Sodic
Khairpur	37,800	165,700	9,200	-
Jacobabad area	193,900	154,200	-	-
Ghotki	25,600	462,700	97,900	-
Nawabshah area	167,700	128,000	-	-
Larkana district	241,900	261,700	74,200	68,500
Hyderabad	15,400	63,300	29,900	-
Sanghar area	481,300	4,500	-	-
Thatta East	407,700	673,900	408,300	-
Totals	1,571,300	1,914,000	619,500	68,500

/a From Reconnaissance Soil Survey Reports of various districts of Pakistan. Directorate of Soil Survey, Lahore, Pakistan, as compiled by Dr. S. Muhammed, University of Agriculture, Lyallpur.

IV. RECLAMATION OF SALINE AND ALKALI SOILS

Saline Soils

4.01 The reclamation of most saline soils is relatively simple provided that drainage is adequate. Sufficient water must be passed through the soil profile, as uniformly as possible, to dissolve the excess salts and move them below the root zone and into the drains for transportation out of the area. The quantity of water required for leaching depends primarily on the salt level in the soil and also on the depth and completeness of reclamation desired. Quality of water and soil texture have little effect. Approximately one unit depth of water is required to leach out (remove) 80% of the salts from a unit depth of soil (i.e., one foot of water per foot depth of soil). Thus, a meter depth of water is required to reduce the salt content of the bottom 25 cm of a meter depth of soil to 20% of its former value and the salt content above this level would be less than 20% of the original value. Where water is in short supply or in slowly permeable soils, it may be desirable to first partially reclaim the land, then plant rice and leach during growth, or plant a salt tolerant crop such as barley before completing the leaching process. In Pakistan, both the lack of availability of water for leaching and facilities for disposal of drainage effluent generally are lacking, hence reclamation of saline soils is not as common as might be expected. In this connection, it must be emphasized that lowering the water table is not sufficient to accomplish desalinization (except in high rainfall areas); water must be passed through the soils.

4.02 Results of attempted reclamation of saline lands in Khairpur SCARP have been discouraging to date as indicated by the following table:

Reclamation Plots - SCARP Khairpur

Sub Sector	Deh	Ave. EC x 10^3, 0 to 3 ft. depth 1970	1971	1972	1973
Pirgoth	Machi	-	13.2	34.0	12.0
Kandhra	Begmanji	108.9	-	34.9	22.3
Kandhra	Kandri	30.3	-	18.9	20.7
Kandhra	Kalhori	7.3	12.5	26.5	24.5
Kotdiji	Husainabad	23.0	207.0	30.7	9.2
Kotdiji	Mithri	-	-	17.7	12.2
Kotdiji	Kanasra	-	180.5	23.7	21.2
Fakirabad	Chodahoo	9.9	-	20.3	3.7
Fakirabad	Fatchpur	-	9.5	50.1	60.2
Fakirabad	Dhukkar	25.7	23.0	36.7	3.1
Stharja	Sha Nawaz	-	-	21.2	47.3
Gambat	Gambat	22.0	54.7	31.8	18.3
Hingorja	Hingorja	45.4	-	36.3	22.7
Kamaldero	Saidi Bala	-	22.1	8.8	17.6
Averages		42.1	65.3	28.0	21.1

If the data are not misleading, only two or three of the 14 plots appear to be reclaimed. Sufficient water for leaching is not passing through the soil because of water shortage or soil impermeability. The salts probably are moved a few inches into the soil profile during irrigation and move back to the surface by capillarity after irrigation. (Reclamation requires deep percolation of salts below the root zone.) After a year of "reclamation", although two appear to have been reclaimed, the 74 plots monitored in Khairpur SCARP during 1973 had on average an EC value of 26.9 millimhos - a level of salinity that does not permit crop production.

Alkali and Saline-Alkali Soils

4.03 It is much more difficult to reclaim alkali than saline soils because alkali soils generally have very low permeabilities, may require the replacement of exchangeable sodium by calcium (provided by an amendment such as gypsum), and the improvement of soil tilth in addition to leaching to get rid of the excess salts originally present or formed by the replacement of exchangeable sodium by calcium. The quantity of amendment necessary for reclamation is determined by the exchangeable sodium content of the soil and the depth of reclamation required. After amendments have been applied and the soil leached, it may be necessary to restore soil tilth by growing crops such as barley, wheat or some grasses for a year or two.

4.04 Waters with high salt contents have been used successfully in many places throughout the world to maintain permeability and as a source of divalent cations for reclaiming sodic soils. A distinct advantage of this method is that, in addition to maintaining a relatively high soil permeability during leaching, the need for gypsum is minimized. Some of the saline groundwaters in Pakistan could be advantageously used for reclamation purposes. A milliequivalent of exchangeable sodium per 100 grams of soils (as determined in a laboratory) is equivalent to 1.7 tons of pure gypsum ($CaSO_4.2H_2O$) per acre foot of soil. Thus, complete reclamation of a sodic soil containing 5 meg of exchangeable sodium per 100 grams of soil would require 8.5 tons of gypsum; in practice, not all the exchangeable sodium need be replaced. It is sometimes desirable to add gypsum to the irrigation water to reduce its sodium adsorption ratio (SAR) to a value of 10 or less to prevent development of a sodic soil (see U.S.D.A. Handbook 60). As indicated above, only a portion of the alkali soils in Pakistan require application of an amendment for reclamation. This is fortunate for gypsum is expensive. The cost of gypsum is related to distance from mines and finess of grind. Crude uncrushed gypsum costs about $1.75 per ton at mine site. Most gypsum for sale in Pakistan is 100 mesh and costs from $10-$16 per ton at the farm. Coarser materials would be much less expensive than the 100 mesh material and probably would be almost as effective. Cost studies for various particle sizes and for large scale deliveries should be made. Numerous reclamation trials, most of them poorly designed or monitored, have demonstrated that almost any of the alkali or saline-alkali soils in Punjab or Sind can be reclaimed, but not the probable cost nor how long it would take.

V. WATER QUALITY, SOIL AND PLANT RELATIONSHIPS

5.01 The quality standards adopted by WAPDA and used in the past for evaluating the suitability of water for irrigation were proposed originally by Tipton and Kalmbach and are similar to standards discussed by IACA (page 41, "Program for the Development of Irrigation and Agriculture" in West Pakistan, Volume 4, Annex 5). Soil problems, which apparently have arisen from use of tubewell waters, have been blamed on adoption of the above water quality standards. 1/ Analysis of about 700 well waters with apparent associated soil dispersion problems seems to show that soil degradation is occurring from use of some groundwaters. This and other reasons recently prompted the Punjab Government to adopt much stricter water quality standards. The new standards are stated to be those proposed by U.S. Salinity Laboratory and adopted by U.S.D.A.

5.02 In February 1954, the U.S. Salinity Laboratory published "Agriculture Handbook 60" which includes a diagram for the classification of irrigation waters and a number of qualifications regarding its use. This diagram, copy enclosed, has been widely used throughout the world since that date. However, as indicated in the text that originally accompanied the diagram, this water quality classification scheme is not suitable for all waters in all situations because of important differences in climates, soils, cropping and water management practices and other conditions.

5.03 In 1967 Dr. Leon Bernstein, U.S. Salinity Laboratory, published a paper entitled "Quantitative Assessment of Irrigation Water" in ASTM STP 416, page 51. The following quotation is from the abstract of this paper.

> "New formulas are proposed in quantitatively assessing irrigation water quality. Except for extremely unsuitable waters, irrigation water quality can be assessed only in the context of the conditions under which the water will be used. These conditions include the infiltration rate of the soil (I), the evapotranspiration rate (E), the irrigation frequency and duration (t_c and t_i, respectively), the net downward drainage rate below the root zone (O), and the maximum permissible salinity and chloride concentration for the crop to be grown (EC and CI, respectively)."

5.04 In 1972 Dr. J.D. Rhoades, U.S. Salinity Laboratory, published a paper in Soil Science, volume 113, No. 4, entitled, "Quality of Water for Irrigation". Quotes from this paper follow:

1/ "A Study of Soil Deterioration Caused by the Use of Different Quality Groundwaters in Sheikhapura Tehsil" by C.H. Jallalludin and C.H. Mohammad Rafiq, June 6-9, 1973.

(P. 279) "Thus, the level of salinity which can be tolerated in the soil water may depend not only on the salt tolerance of the crop to be grown, but also on the distribution of salinity in the soil profile, on the frequency and extent to which soil water is depleted between irrigations, and on the water content of the soil ..... Thus, irrigation management can be expected to affect permissible levels of salinity in irrigation waters."

(P. 280) "Eaton considered the precipitation of Ca and Mg by carbonates to be quantitative and proposed the concept of "residual Na_2CO_3" for evaluating high-carbonate waters. This concept is not generally meaningful because (1) soils irrigated with waters containing appreciable amounts of HCO_3, but having no "residual Na_2CO_3," may produce ESPs in excess of that predicted by SAR_{iw}; (2) the precipitation of Ca and Mg by carbonates is not quantitative; its extent varies with leaching fraction and soil atmospheric CO_2 concentrations; and (3) the Ca and Mg released to the irrigation water upon reaction with the soil by mineral weathering processes act to offset the effects of lime precipitation."

(P. 281) "A major point that has prevailed throughout this treatise is that it is presently impossible to set precise standards of wide applicability for irrigation water. The suitability of an irrigation water needs to be evaluated on the basis of the specific conditions under which it will be used including crops being grown, soil properties, irrigation management, cultural practices, and climatic conditions."

5.05 The United States Bureau of Reclamation also recognize that no single standard for water quality is adequate for evaluating the suitability of water supply. In 1969 (approximate date) the Bureau formally adopted a policy of evaluating the suitability of waters for irrigation on the basis of local soil, climate, and cropping conditions. There are many cases where waters are successfully used that might be considered very hazardous or unsuitable according to Handbook 60 or almost any other common set of criteria. For example, Table 1 gives the location and crop yields of 1,157,000 acres of crops in Western United States irrigated with water containing soluble salts in excess of 1,150 ppm (EC x 10^6 of 1800). It will be noted that in one instance a water containing 7,500 ppm of salts has been and is being used successfully on 11,000 acres of crop land.

5.06 Another example of the successful use of "poor" quality irrigation water is in New Mexico 1/ where two waters which would be C3-S4 according to Handbook 60 have been successfully used for irrigation for about 17 years with yields steadily increasing. These waters have RSC values of 7.1 and 7.0, SAR values of 30 and 36, and EC x 10^6 values of 1,310 and 2,050. A quote from the paper follows:

> (P. 361) "This study supports observations that have been made on the critical level of ESP for cotton growth on fine textured soils in southern New Mexico. Good yields have been obtained on soils having an ESP of 20 to 25. The data presented here indicate that the critical level of ESP for cotton grown on fine textured soils in this area is about 25 in the surface soil."

5.07 The water quality standards, as set forth in Handbook 60, were based in part on the premise that the physical properties of average soils are seriously affected by exchangeable sodium percentage levels of about 15. This is true for soils containing an appreciable amount of montmorrilonite clay, but it is not true for soils dominated by illite or kaolinite clay minerals. Soils in the Indus Basin contain mainly illitic clay minerals and their physical properties are adversely affected by exchangeable sodium at levels of about 25 to 30 rather than 15%.

5.08 Other reasons for not adapting such conservative standards are the variabilities within the Punjab in soil texture, soil permeability, amount of soil gypsum, water table levels, rainfall, net evaporation, location on the watercourse, cropping pattern, irrigation practices and quality of groundwater. Any or all of these factors can influence the standards which should be adopted locally. For these reasons, it is suggested that flexible standards be utilized in Pakistan that permit, for example, use of lower quality water for (a) rabi crops because of lower evaporation in winter, (b) permeable sandy soils where leaching can be easily accomplished, (c) soils used for rice culture as there is little opportunity to concentrate salts with this crop, and (d) soils on the upper portions of watercourses where the water supply commonly is ample for both crop growth and leaching.

5.09 Each feasibility report involving irrigation development should include a discussion on water quality and standards taking into account variability in soils, cropping patterns, rainfall, etc. in support of the standards adopted. The possible use of gypsum and recommendations on how to use marginal quality waters successfully should also be included if possible as well as economic evaluations of the costs and associated benefits of utilizing low-quality waters.

1/ Soil Science 1972, Volume 113, No. 5: "Short-Term Effects of Irrigation with High Sodium Waters" J.U. Anderson, O.F. Bailey, and H.E. Dregne.

VI. GROUNDWATER AND DRAINAGE

Groundwater Status

6.01 The 1973 high rainfall and resultant flood caused a general rise in water tables throughout the country; the effects were most dramatic in the Punjab. In Rechna Doab the average rise in groundwater level was 2.74 feet over an area of 7.6 million acres and the estimated increase in water storage was 5.16 million acre feet. In Chaj Doab, the average rise was 3.99 feet over an area of 2.82 million acres for a gain of 2.25 million acre feet in groundwater storage. In a survey of representative wells in the Punjab, the average water table level in Oct. 1973 was 0.7 foot higher than in October 1972. Areas in the Punjab having water table levels in the 0 to 5 foot depth for several dates are shown in the table in para. 6.02. There was no significant difference in water table level between June 1972 and 1973, but a 3% increase in "waterlogged" area from Oct. 1972 to Oct. 1973.

6.02 Average water table levels in SCARP I apparently have stabilized at a depth of around 18 feet. In June 1972 in SCARP I, the water table level groups were as follows: less than 5 feet, 0.5%; 5-10 feet, 8.6%; 10-15 feet, 32.1%; 15-20 feet, 43.8%; 20-25 feet, 12.2% and, over 25 feet, 2.8%. The Central Monitoring Organization stated that current annual pumpage from public tubewells is 1.66 M ac-ft and from 1,861 private tubewells, 0.72 M ac-ft, for a total pumpage of 2.38 M ac-ft. The long term "safe yield" is estimated by CMO to be 2.04 M ac-ft. Water table levels in SCARP II have declined as follows:

(a) Phalia Scheme: The water table has declined an average of 2.5 feet to a depth of about 10 ft. since commissioning in 1968-69.

(b) Sohawa Scheme: The water table declined 3.5 feet from 1967 to June 1972.

(c) Busal Scheme: The water table has declined by about 6.5 ft. since commissioning in 1968-1969.

(d) Lower Hujjan Scheme: A total lowering of about 1 ft. in the W.T. level has been achieved since commissioning in 1968-69.

(e) Khadir Scheme: The average lowering of water table was 4.1 ft. since commissioning in 1969.

(f) Lalian Scheme: A net lowering of about 3.6 feet in the groundwater table was achieved since commissioning in 1963-1964.

(g) Kot Momin Scheme: The groundwater table has been lowered 2.9 feet since commissioning of wells in 1970.

Areas with High Water Tables - Punjab [/a]

Area	Gross Acreage	Percent of Area with W.T. at 0 to 5 ft level June, 1972	June, 1973	Oct. 1972	Oct. 1973
Chaj Doab	3,229,000	3.5	3.8	9.7	15.2
Rechna Doab	6,916,000	1.5	1.6	3.3	6.6
Bari Doab	7,452,320	1.4	1.4	2.0	3.3
Thal Doab	5,632,000	6.4	5.0	6.5	5.8
Dara Jat	4,485,120	11.6	9.3	20.2	28.9
Sutlej Valley	5,826,960	8.4	8.6	11.2	14.9
Total Punjab	33,541 400	5.0	4.6	7.8	11.0
		1.8	1.6	2.8	3.9 M ac

/a Data developed by Directorate of Land Reclamation, Irrigation and Power Department, Punjab.

6.03 The only available data on water table levels in the Sind are from Khairpur SCARP. The average depth to water of 200 tubewells was 10.12 feet in June, 1972 compared to 8.63 feet in June, 1973. The water table rose considerably in December, 1973, apparently as a result of subsurface flows from the previous Punjab high rains and flood.

Drainage

6.04 A comparison of tubewell versus tile drainage is a subject for debate throughout Pakistan. Owing to water quality problems, reduction of pumping capacity and maintenance problems, some officials have become disenchanted regarding tubewells. The growing need to drain areas with highly saline groundwater and satisfactory means of disposing of the saline effluent are problems that have not been resolved. Options range from mixing some of the saline effluent with canal water (and thus increase the average salinity of the irrigation water), disposal of the effluent into a remote evaporation pond, disposal into the river, or construction of a very long expensive outfall drain to the sea. At best mixing with better water can be only a temporary measure as it will increase the salinity of the downstream supplies; evaporation requires huge evaporation basins in non-arable areas and perhaps lining to prevent excessive leakage into potable groundwaters. Disposal into the river is possible for a few months only, when flows are sufficient for adequate dilution of the mixture for downstream use. Serious consideration should be given to construction of a small outfall drain from the Punjab which could be integrated with the proposed Sind Left Bank Outfall drainage project. At least two million acres within the Punjab are underlain by highly saline groundwater (over 3000 ppm) and a much greater area is underlain by saline water in the Sind. About 39% of the groundwater of the upper Indus contains soluble salts in excess of 1,000 ppm, whereas 88% of the Sind groundwater is in excess of 1,000 ppm, and at present there is no way to properly drain most of these lands.

6.05 Tile drains offer a means of minimizing the magnitude of drainage effluent problem; these could effectively skim the saline groundwater from the upper part of the aquifer. Once this was removed, the quality of the effluent would be much improved, enough to be satisfactory for irrigation. However, this would require cessation of water spreading - i.e., applying less than the full irrigation requirement to crops.

VII. SOIL AND WATER RESEARCH REQUIREMENTS

7.01 General. The research requirements presently include:

(a) Farm management practices to best utilize low quality irrigation water (mostly from tubewells). Also, use of gypsum in lowering the SAR of waters (through treatment of the soil or the water.

(b) Salinity/fertility/crop yield relationships, with and without fertilizers.

(c) Leaching to remove salinity: amount of water required, best time to apply, costs, etc.

(d) Alkali (sodic soil) reclamation: kind and amount of amendments, length of time and water required, associated costs, etc.

(e) Establishment of master site soil locations to represent normal, saline, alkali, and waterlogged soils and monitoring studies thereon to evaluate seasonal changes in salinity and alkali under average and improved water management practices.

(f) Updating of soil salinity mapping on a national basis, and quantification of areas affected as well as their current production and future production potentials.

7.02 Sind Soil and Water Problem Priorities

(a) Better water management practices (these could possibly result in significant reduction in the amount of water required for irrigation and a concommitant reduction in drainage requirements.)

(b) Drainage problems - their assessment and means of solution.

(c) Improved on-farm technology and management practices to minimize damage from salinity and waterlogging.

(d) Reclamation studies of saline and alkali soils.

(e) Improved planning and implementation on other agricultural aspects related to crop productivity.

(f) Implementation of soil and water monitoring programs.

7.03 Punjab Soil and Water Problem Priorities

(a) Studies on use of marginal or hazardous quality tubewell waters, including the need for and the economical use of gypsum to offset the adverse effects of poor quality irrigation waters.

(b) Disposal of drainage effluent from highly saline high groundwater areas.

(c) Studies to determine where horizontal (tile or open ditch) drains may be better than vertical (tubewell) drainage.

(d) Improved on-farm land development to increase irrigation efficiency.

(e) Salinity reduction in lands with low water tables.

(f) Soil and water monitoring in addition to SCARP I and Mona projects.

VIII. SOIL AND WATER RESEARCH ACTIVITIES

8.01 Soil and Water Monitoring - The Central Monitoring Organization (CMO) was established under WASID in November, 1968 to undertake and coordinate all monitoring activities related to hydrology, water quality, soils, agriculture, and economics in existing and proposed reclamation projects. The Water and Soil Investigation Division (WASID) was dissolved in 1972 in the reorganization of WAPDA and CMO was transferred directly to WAPDA.

8.02 The CMO is understaffed and under-financed and is not able to do nearly as much monitoring as desirable. Most of its work has been in SCARP I but it has done some hydrologic monitoring in other SCARPS. In SCARP I, CMO monitors (a) soils being irrigated with varying qualities of water, (b) changes in discharge and water quality in public tubewells, (c) changes in water table levels, and (d) changes in land use.

8.03 The work of CMO probably should be expanded to include evaluation of the amount of land being "reclaimed". The Department of Irrigation and Power now estimates the extent of reclamation in the SCARP areas by observation alone. In some instances lands are listed as reclaimed when the water table drops below 10 ft. in depth even though soil salinity or alkali is excessive.

8.04 Some salient results of monitoring in SCARP I are as follows:

(a) By 1972 the average ground water level was 10.3 feet lower than in 1962-63.

(b) Poor quality irrigation water is adversely affecting the physico-chemical characteristics of some soils.

(c) Overall, areas using hazardous and good quality water have decreased by 1.3 and 0.6% respectively while areas using marginal quality water have increased 2.9%.

(d) Progress of soil reclamation is very slow. Out of 70 sampled saline-alkali (sodic) plots, only 10% are fully reclaimed, 23 per percent are now non-saline alkali, and the remainder (67%) are still saline-alkali.

(e) Cropped acreage has increased from 913,800 acres in 1958-60 (base period) to 1,272,800 acres during 1971-72. There has also been an increase in crop yields so that total production has been greatly increased.

8.05 Mona Project, Punjab (WAPDA/Colorado State University) - Very useful soil and water research is in progress. The following pertinent experimental studies will be conducted during 1974:

(a) Determination of the leaching requirement of soils irrigated with waters of different salinity levels. (Two years of results indicate that neither 25 nor 50% leaching caused significant changes in crop yields, infiltration rates, or soil chemical properties.)

(b) Effect of tubewell waters of different SAR values on soil properties and plant growth. This study, started in 1969-70, uses tubewell water from 6 wells with SAR values ranging from 5 to 20. (Results to date show that tubewell waters having SAR values of 15 or more have adversely affected soil conditions and plant growth.)

(c) Effect of tubewell waters of different residual sodium carbonate (RSC) values on soil conditions and plant growth has just been started. The waters have RSC values ranging from 2.1 to 7.2, SAR values from 5.9 to 9.8, and total dissolved solids from 464 to 832 ppm. Gypsum is being used at 50% and 100% of the calculated requirement to modify water quality.

(d) The rate of reaccumulation of salts in reclaimed land; started in 1969. (This study shows that salt accumulation is higher under fallow than with continuous cropping.)

(e) Study of soils irrigated from 48 tubewells whose water are considered hazardous because of high SAR and RSC. (Started in 1967-68, there has been a gradual increase in SAR with little change in soil salinity or pH.)

(f) Effect of irrigation interval on soils and crops receiving waters of different salinities; just started.

(g) Determination of optimum dose and interval of gypsum application on soils being irrigated with high SAR waters. Just started, the treatments include 25, 50, 75 and 100% of the calculated gypsum requirement, and varying grinds of gypsum from 0.1 inch diameter to 100 mesh.

(h) Study is just starting to determine rates of solubility of gypsum of different particle size in tubewell water of differing qualities.

8.06 Punjab Agriculture Research Institute, Lyallpur - Experiment on water quality in which irrigation water of "poor" quality (EC x 10^3 = 3.6, SAR = 16, RSC = 6.8) is being applied with and without mixing with 175 ppm canal water. Treatments include canal water, mix to 1,000 ppm, mix to 2,000 ppm and straight tubewell water, with water applications varied to include consumptive use (CU) plus various percentage of leaching. Results of the first year's studies are as follows:

Results of Leaching Trials

Water	CU + Extra For Leaching	Wheat Yield (Maunds Per Acre)
Canal	0	46.28
"	10%	45.85
"	20%	42.36
1000 ppm	10%	43.78
"	20%	43.12
"	30%	47.15
2000 ppm	15%	48.78
"	30%	48.57
"	45%	49.44
2700 ppm	30%	49.66
"	45%	44.84
"	60%	46.72

8.07 As is evident, the preliminary results show no decrease in yield from use of copious quantities of the highly saline tubewell waters. It will be advisable to keep informed of future yields and soil changes in this experiment.

8.08 Irrigation Research Council - A Central Government sponsored research organization, located in Lahore, deals strictly with basic research. Two projects in the field of soil and water are of particular interest. First, a Monograph on Waterlogging and Salinity Problems in Pakistan is being compiled; it was in draft stage in February, 1974, and contained 1331 references relating to all known studies done in Pakistan. The second project, just getting well started, involves very sophisticated lysimeter studies with the objective of determining bare soil evaporation with the water table at varying depth, from 0 to 20 feet. Also they will study consumption use and irrigation requirements under the varying water table conditions.

IX. TECHNICAL ISSUES ENCOUNTERED

9.01 The Irrigation and Drainage Review Mission discussed a number of soil and water issues with the Federal Government among which were the following:

9.02 Criteria for Groundwater Suitable for Irrigation. Owing to adverse experiences with some tubewell water in SCARP I, the Punjab Government recently adopted extremely strict (i.e., conservative) quality of water standards for irrigation. The new and old standards are as follows:

Water Quality Standards

		New Standards for Irrigation Water	
Good Quality		Marginal	Hazardous
ppm	0 - 475	476-800	800
SAR	6	6-11	11
RSC	1.25	1.25-2.50	2.5

		Previous Standards for Irrigation Water	
Good Quality		Marginal	Hazardous
ppm	0-1000	1000-2000	2000
SAR	10	10-18	18
RSC	2.50	2.5-5.0	5.0

Under the new quality standards, 1,262 of the 2,038 public tubewells in SCARP I would be in the hazardous category compared to 506 under the previous standards; also now only 186, or 9%, of the well waters would be considered useable without mixing in comparison to 747, or 36.6%, previously.

9.03 It was stated that the new standards were in accordance with the criteria adopted by the USDA and set forth in Handbook 60. However, this is not correct. This 1954 publication lists the criteria for water suitability as a combination of both salinity and sodium hazards. The best water, C1-S1, has an electrical conductivity of less than 250 and an SAR of less than about 10. Category C2-S1 has an electricial conductivity between 250 and 750 and an SAR between 6 and 8. These two waters correspond approximately to the water which, according to the new Pakistani standards, can be used without mixing. Handbook 60 standards, however, include a range of water quality categories with varying degrees of suitability which can be used without mixing provided sufficient water is applied during irrigation to achieve some leaching. For example, category C2-S2 designates water with an electrical conductivity up to 750 (about 478 ppm) and an SAR up to 16 as having only medium salinity and sodium hazards whereas such waters are marginal to hazardous according to the new Pakistani criteria. The U. S. Salinity Laboratory, the Bureau of Reclamation, UNESCO and other organizations dealing with quality of water standards recognize that suitability for irrigation depends among other things on soil permeability, type of clay mineral, climate, cropping pattern, drainage conditions and irrigation water management with the last probably the most important parameter.

9.04 Use of so-called "poor" quality water under present management practices has caused soil deterioration in SCARP I and possibly elsewhere. However, it should be noted that the degree of soil deterioration varies greatly among farmers using the same supply. Even canal water alone can harm a soil if the water is used so sparingly that none passes through the soil to maintain a favorable salt balance. Two conditions combine to create more problems with water quality in Pakistan than in many other developing areas: (a) the general shortage of water over most of the country results in application of too little water to crops. (This causes accumulation of salts and precipitation of calcium with resulting increase in the proportion of sodium and this in turn tends to disperse the soil.); (b) dispersed soils require more power for manipulation. (Bullock power, which predominates in Pakistan, is too limited to achieve good tilth in dispersed soils and crop population may be decreased.)

9.05 As regards water quality, the principal problem apparently is in SCARP I where as much as 400,000 acres may have been adversely affected to some extent. The solution is not to change standards. Application of sufficient water to effect leaching, mixing, or addition of small amounts of gypsum, could eliminate or minimize the problem. Owing to the predominance of non-swelling illite type clay minerals, a relatively high ESP is required to "damage" soils, and also the affected soils respond quickly and favorably to gypsum applications.

9.06 Availability of Water for Leaching. Water table levels have been lowered in several SCARPS by pumping, but there has been little increase in leaching to remove salts owing to lack of water or of comprehension by the farmer that it is important to add enough water to ensure leaching and thereby remove excess salts from soils. One constraint is the local distribution systems which do not permit selective delivery of water to individual farms for leaching. Lack of adequate leaching is most acute in the Sind, but probably is not an important factor in soil salinity in areas where annual rainfall exceeds 15 inches.

9.07 Intensive vs. Extensive Irrigation. Owing to the unavailability of adequate irrigation water supplies during critical periods of crop growth, farmers commonly do not plant their entire holding. Soil salinity increases if the land is not irrigated — particularly where the depth to water table is less than 10 feet. Land should be irrigated in both kharif and rabi seasons if possible; this would result in less soil salinity and higher crop yield per unit of land (but not per unit of water). In the portion of the farm adequately irrigated, fertilizer usage would be more efficient, soil salinity would be lower and crop production higher. Demonstrations plots and extension activities can demonstrate the merits of this approach.

9.08 Constraints on Reclamation. Although not a major issue, there is still much saline land in SCARP areas even though water table levels are low, on average. This occurs because considerable acreages within the SCARP areas have water tables still close to the soil surface owing to topographic lows. The table in para. 6.02 shows the acreage involved. There are 10 to 15 foot differences in elevation over a few miles in some Scarps even though regional topography is moderately flat; groundwater pumping to a satisfactory depth in the higher areas still leaves water table within 5 ft. of the soil surface in topographic lows. Such areas act as salt sinks and there appears to be no easy means of reclaiming them.

X. SALT BALANCE

Introduction

10.01 Quality of groundwater and salinity status of soils commonly are adversely affected by regional irrigation development. Irrigation water containing salts in solution is imported into the region and typically most of the water is lost through evaporation and transporation, but the salt remains behind in both soils and groundwater. Accordingly, if leaching, drainage and disposal of affluent are not adequate, the salt content of both soils and groundwater will increase and in time reach intolerable levels. Under these conditions, the salt balance, the trend in the relation between the amount of salt being imported to that being exported, would be unfavorable. 1/

10.02 Salt balance problems are more complex in Pakistan than in most irrigated areas. The land slopes averages only about one foot per mile, there are few drains and little drainage relief except close to rivers, and disposal

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1/ Ordinarily the volume of drainage required to maintain a favorable salt balance - s from one-tenth to one-seventh the total water inflow; thus, in the absence of precipitation the salt concentration of the effluent would be from five to seven times that of the applied irrigation water.

of saline drainage effluent is difficult or impossible most places. The main sources of ground water recharge are seepage from rivers, leakage from canals and distributaries and losses during irrigation. Although the canal water is of excellent quality (i.e., is low in salt content) so much water is imported into the Indus Plains for irrigation (about 90 M ac-ft) that the amount of salt left in the soil and groundwater by evaporation and transppiration is enormous--more than 20 million tons per year.

10.03 Various estimates have been made on the need for drainage and/or salt balance. The President's Science Advisory Committee "Report on Water-logging and Salinity in West Pakistan", 1962 1/ on the basis of a sophisticated salt flow model, stated: "Surface drainage of about 10 percent is unnecessary and less than 5 percent is ineffective. In most cases pumping for drainage can be delayed for 10 or even 20 years without excessive salt buildup, providing that total drainage in 50 years is equal to about 10 percent of total pumping." Twelve years have passed since this was written and no sizeable drainage systems have yet been provided. Plans for the Punjab seem to be in abeyance pending completion of plans for a Left Bank Outfall Drain for the Sind which might feasibly be extended into that Punjab. A Right Bank Outfall Drain for the Sind also is in the planning process.

Calculation of Salt Balance

10.04 Attempts have been made to calculate the salt balance status of major reaches of the Indus Basin. The data used in some of these calculations as well as approximate current and anticipated annual changes in the salt content of the groundwater are given in Tables 2.1, 2.2 and 2.3 attached.

The assumptions and calculations used in the case of Lower Indus areas are as follows:

(a) Given or assumed:

(1) Annual importation of surface water into area = 3.92 ft/ac gross area.

(2) Net groundwater inflow from upslope area is estimated to be 0.30 ft/ac gross.

(3) Groundwater pumpage = 0.41 ac-ft/ac. 2/

(4) Average salt content of surface water is 225 mg/l. 3/

1/ The so-called "White House" or Revelle" Report.

2/ IACA Report, Annex 7, 1966.

3/ One milligram per liter (mg/l) = 2.7 lb/ac-ft of water. Thus, depth of water in ft x mg/l x 2.7 = pounds of salt per acre.

(5) Average salt content of groundwater is 800 mg/l.

(6) Distribution losses from point of entry into area to head of watercourse = 0.90 ft/ac. (23 percent 1/).

(7) Losses from head of watercourse or well to field = 0.84 ft/ac (24.4 percent 1/).

(8) Rainfall that reaches the groundwater aquifer, i.e. effective rainfall, is zero (for this area).

(b) Calculations

(1) Available for irrigation is 3.92 + 0.41 + 0 - 0.90 - 0.84 = 2.59 ft/ac.

(2) Amount of water evaporated at and near the soil surface = 2.59 - 0.41 + 0.30 = 2.48 ft (since groundwater is at equilibrium).

(3) Salts brought into system = 3.92 x 225 x 2.7 + 0.30 x 800 x 2.7 = 3.029 lb/ac.

(4) Average salt content of applied wster = (3.02 x 225) + (0.41 x 800) ÷ (3.02 + 0.41) = 2.94 mg/l.

(5) Salt deposited in surface soil by evaporation = 2.48 x 29.4 x 2.7 = 1.968 lb/ac.

(6) Annual increase in salt content of aquifer 2/ = $\frac{3{,}029 - 1{,}968}{44 \times 2.7} = 9$ mg/l.

(7) The potential annual increase in the salt content of the groundwater is the total amount of imported salt distributed in the usable aquifer = $\frac{3{,}029}{44 \times 2.7} = 25$ mg/l/yr.

Discussions of Values and Implications

10.05 The salt balance of the Indus Plains apparently is changing little if at all at present because the soil is acting as a salt sink, i.e., soil salinization is on the increase. When water table levels are approximately 10 feet or less from the soil surface, appreciable amount of salts move upward by capillarity into the soil surface if the land is not copiously

1/ IACA Report, Annex 7, 1966.

2/ Assuming no precipitation or other losses in aquifer, and that the salts are evenly distributed throughout aquifer.

irrigated. And, wherever the groundwater level is within 3 or 4 feet of the surface, upward movement of salts is extremely high for evaporation is almost as high as from a free-water surface. Thus, the water level tends to drop as a result of evaporation but is renewed by river or canal seepage plus deep percolation losses during irrigation. Accordingly as most of the added salt accumulates on the soil surface, the concentration of the groundwater changes but slowly. Everything being equal, the fresh groundwater aquifers in SCARP areas, would be expected to degrade at a more rapid rate than the non-SCARP areas--particularly where the groundwater is maintained more than 10 feet below the soil surface. Under this condition, relatively little salt is deposited on the soil surface by capillarity and most of the salt load is moved by irrigation seepage into the groundwater.

10.06 Thus, the groundwater of the average SCARP will deteriorate at a slowly increasing rate, starting at about 9 or 10 mg/l/yr until outlet drains are provided. As the average salt content of groundwater is now about 600 ppm in Punjab and 800 ppm in Sind, and 1,000 to 1,200 ppm or more of salts in irrigation water is tolerable for most crops, it will take 30 to 40 years under present conditions (i.e. without leaching or drainage) for the groundwater to become "bad." At the present time, about 8% of the CCA of the Punjab and 35% of the Sind have the water table in the 0 to 5-foot depth range. In these areas, the land undoubtedly is acting as a salt sink and the rate of deterioration of the groundwater is substantially reduced thereby to virtually zero, whereas where water table levels are at 10 to 12 feet groundwater deterioration has been shown to be about 10 mg per liter per year.

10.07 However, if in addition to groundwater levels being lowered, the salts now present in the soil are leached downward into the aquifer and are not drained away, the salinity of the groundwater immediately will increase substantially. A rough calculation will indicate approximately how much salt would be involved in a leaching program and what this could do to water quality.

> If we assume the average soil in Pakistan has an electrical conductivity of 6 millimhos per cm and a saturation percentage of 50, then the soil contains about 0.25% of salt by weight. An ac-ft of soils weighs about 4 million pounds. If we consider only the surface five feet of soil, the soluble salt content is 0.25% of 20 million pounds, or about 50,000 pounds per acre. If only half of this were moved into the groundwater aquifer by leaching, it would immediately increase the average salt concentration of the entire aquifer as follows: 1/

$$X = \frac{50,000}{2} \div \frac{1}{44 \times 2.7} = 210 \text{ mg/l}$$

1/ Assuming, as in the previous example, that the aquifer depth is 200 ft, that it contains 44 ft of water and that there would be complete mixing of the salts into the water.

Thus, wherever a serious effort is made to reclaim saline soils, groundwater quality will deteriorate rapidly if drainage facilities are not available to remove the saline effluent.

10.08 Areas with saline groundwater at shallow depth require drainages for two reasons: (1) reclamation of soil overlying shallow saline aquifers is impossible until the groundwater level is lowered; and (2) maintenance of a high level of saline groundwater (water table mound) adjacent to fresh groundwater areas at lower levels will result in lateral movement of water from the higher (saline) to the lower (fresh groundwater) area with consequent increase in salinity of the fresh groundwater.

10.09 The problem of salt export is complicated because: (a) most of the irrigated land is a great distance from the sea or other suitable site for diposal of effluent, and (b) the inadvisability of dumping saline effluent into rivers because of downstream diversions for use. But, a large outfall drain eventually will be required for the Indus Plains despite its extremely high cost. Prior to the time this outfall is available, some effluent can be disposed into rivers, some diverted into evaporation ponds and small outfall drains could be used to advantage in a few places. The amount of saline groundwater in the Punjab alone is shown below:

Region	Quality of Groundwater in Punjab (millions of acres) 1,000 ppm	1,000-3,000 ppm	3,000 ppm
Thal Doab + Indus R. B.	2.03	0.99	0.60
Chaj Doab	1.19	0.36	0.49
Rechna Doab	3.37	0.84	0.49
Bari Doab	3.95	2.34	0.54
Total	10.54	3.53	2.12

Since more than 2 million acres are underlain with groundwater of high salinity, there is a near-term need to provide outlet drains, especially wherever the groundwater level is less than 20 feet. If an average irrigation application is assumed to be 3 ac-ft per acre per year and the drainage requirement is 20 percent of applications, an export of 1.27 M ac-ft or a continuous flow of about 1,760 cfs would be required for maintenance of the status quo of the saline groundwater area of the Punjab alone. In actuality, the amount would have to be disposed of would be somewhat less because some of the outflow could be reused for irrigation once the initial flushing of salts from the soil was over. A continuous outflow of, say 800 cfs, probably would take care of the more urgent salinity export problems of the Punjab for the next few decades; a much larger facility would eventually be needed.

Effect of Tarbela on Salt Balance

10.10 Arrangements for the distribution of stored Tarbela water for irrigation had not been made at the time of the Mission's visit to Pakistan. Many canal systems are not properly prepared to receive the new source of water, since the prevailing drainage conditions in extensive areas preclude its wide use without adverse effects unless improved drainage is installed, or unless water management is improved on watercourses and farms, or unless both occur to some extent. Hence, planned distribution could have an unfavorable impact on groundwater hydrology. That is, water tables would rise with resulting increase in salinization of soils except in the few SCARP and other areas with deep groundwater levels. The general conclusions with regard to salts balance are given in Section XI.

XI. CONCLUSIONS

(a) WAPDA type soil surveys are more useful than those of the Soil Survey of Pakistan for irrigation and drainage investigations and project appraisals.

(b) Aerial photographs being used for soil survey work were mostly taken in 1953 and are almost obsolete. New aerial photographs are needed of the entire country.

(c) Topographic data are available or can be prepared and do not pose a constaint to adequate project planning. Remote sensing might help Pakistan in such subjects as land use surveys, cropping patterns, changes in groundwater conditions, and changes in soil salinity. Orthophotography also might be useful. The Office of Surveyor General of Pakistan would like to update their facilities and may request assistance from the World Bank in this endeavor.

(d) The Central Monitoring Organization is well conceived and well directed but under-financed for achievement of its objectives.

(e) Salinity and groundwater problems are much more severe in the Sind than in the Punjab.

(f) More accurate information is needed on the acreage of saline and alkali soils, degree of severity of problems, comparative yields and production (without and with fertilizers) in saline areas, and present trends, especially in Punjab and Sind but also in canal command areas of the other two Provinces.

(g) Greater use of gypsum may be helpful to correct alkali soils and to reduce the sodium absorption ratio of some groundwater used for irrigation.

(h) Research on soils, of the sort in progress in the Mona Project, is needed elsewhere, particularly in the Sind.

(i) Studies are needed on cost of delivery of various amount of gypsum of different particle size to the farm.

(j) Tile drainage facilities are needed in some saline groundwater areas for saline effluent removal.

(k) The Agricultural Research Institute at Lyallpur should continue studies on use of poor quality irrigation water.

(l) The monograph on salinity problems in Pakistan by the Irrigation Research Council should be made available to the World Bank.

(m) The implications of the alternative water quality standards for use in Punjab should be carefully reconsidered in light of their effect on resource development potentials.

(n) The salt content of the groundwater is increasing slowly because the soil is acting as a salt sink.

(o) Groundwaters will become more saline at a substantially faster rate in the Sind than in Punjab under SCARP programs.

(p) An outfall drain is needed for the Sind in particular if soil deterioration is not to continue a pace.

(q) There is need for a smaller outfall drain for the Punjab to permit leaching for reduction of soil salinity and to maintain appropriate water table levels particularly in the 2 million acres underlain by saline groundwater.

(r) Changes in the groundwater salinity of fresh water zones in the Punjab are gradual, and absolute need for a large outfall drain can be delayed an estimated 30-40 years, at which time the groundwater probably will contain between 800 and 1,000 ppm. Groundwater quality will not deteriorate appreciably near rivers and large canals.

(s) Distribution of stored water supplied from Tarbela without provision for drainage will tend to increase drainage problems in both Punjab and Sind.

(t) Peshawar Vale probably will not need an outlet drain, for the relatively small volume of effluent that must be removed for salinity control could be dumped into the river during high flow periods.

(u) More precise data are needed to more accurately evaluate the salt balance problem in the Indus Plains.

TABLE 2.1

Estimates Used for Salt Balance Calculations

Canal Command Locations	Annual Rainfall (Inches)	Deep Perc. of Rainfall (Ft/yr)	Annual Canal Delivery[1/] (Ac-ft Per Acre)	Ave. Salt Content of Canal Water (mg./l)	Ave. Salt Content of Ground Water (mg./l)	Gross Area (Million Acres[2/])
Peshawar Vale	12	.25	2.76	140	450	0.68
Thal Doab	10	.20	1.39	165	600	3.62
Chaj Doab	14	.29	1.37	165	600	2.04
Rechna Doab	12	.25	1.48	165	600	4.70
Bari Doab	10	.20	1.96	165	600	5.83
Sutlej & Panjnad	5	0	2.14	200	800	3.51
Lower Indus	5	0	3.02	225	800	8.98

1/ To head of watercourse (conveyance losses = 0.90 ft for Lower Indus); calculated from gross acreage and average surface supply for relevant development conditions in 1975. From Table 6.4, Annex 7, Report of Sir Alexander Gibb and Partners, May 1966.

2/ From Volume 5, Annex 7, Water Supply and Distribution, IACA, May 1966.

TABLE 2.2

GROUNDWATER INFLOW AND OUTFLOW BALANCE (ACRE-FEET)

Area	Aquifer Depth Under Consideration (Ft)	Water Contained In Aquifer 1/ (Ft)	Conveyance Losses Above Watercourse (Ac-Ft/Ac)	Irrigation Losses Below Watercourse (Ac-Ft/Ac)	Net Groundwater Inflow (Ac-Ft/Ac)	Deep Percentage Of Rainfall (Ac-Ft/Ac)	Groundwater Pumpage (Ac-Ft/Ac)	Evaporation (Ac-Ft/Ac)	Assumed Change In Groundwater Elevation (Ft)
Vale of Peshawar	200	44	0.68	0.62	-0.3	0.25	0.04	1.25	0
Thal Doab	200	44	0.60	0.63	0.2	0.20	1.07	0.56	0
Chaj Doab	200	44	0.68	0.48	0.2	0.35	1.43	0.28	0
Rechna Doab	200	44	0.75	0.58	0.2	0.35	1.70	0.18	0
Bari Doab	200	44	0.80	0.74	0.2	0.20	1.31	0.63	0
Sutlej and Panjnad	200	44	0.74	0.94	0.2	0	0.91	0.97	0
Lower Indus	200	44	0.84	0.90	0.3 2/	0	0.41	2.48	0

1/ Calculated for achievement of equilibrium water table conditions.

2/ Estimated.

TABLE 2.3

SALT DEPOSITION AND CHANGES IN QUALITY OF GROUNDWATER

Area Under Irrigation	Salt In Surface Water (lb/ac)	Salt in Net Groundwater Inflow (lb/ac)	Total Salt Import (lb/ac)	Salt Deposited In Soil By Evaporation (lb/ac)	Difference In Total Salt Content (lb/ac)	Estimated Annual Groundwater Change (ppm)	Potential Annual Groundwater Change[1/] (ppm)
Vale of Peshawar	1,091	-364	1,325	996	-84	0	8
Thal Doab	2,352	324	2,956	579	+644	5.4	10
Chaj Doab	2,927	324	3,465	290	+853	7.2	10
Rechna Doab	3,413	324	3,995	186	+1,055	8.9	10
Bari Doab	2,995	324	3,648	844	+682	5.8	13
Sutlej and Panjnad	3,122	452	4,082	1,310	+806	6.7	18
Lower Indus	2,381	648	3,029	1,968	+1,061	9.0	25

1/ Assuming all salts imported are distributed in aquifer and none are precipitated or otherwise lost from the system.

T. N. No. 2
Table 2.4

P A K I S T A N

IRRIGATION AND DRAINAGE

AREAS UNDERLAIN BY VARIOUS DEPTHS TO WATER TABLE

PUNJAB, 1972 AND 1973

(Thousands of Acres)

DOAB (Between Rivers)	MONTH	DEPTH AND YEAR 0 Ft - 5 Ft		DEPTH AND YEAR 5 Ft - 10 Ft		DEPTH AND YEAR Over 10 Ft.	
		1972	1973	1972	1973	1972	1973
CHAJ (Chenab & Jhelum)	June	112.6	122.6	1,341.4	1,264.2	1,774.9	1,842.2
	October	312.9	491.5	1,156.7	1,199.3	1,759.4	1,538.2
RECHNA (Ravi & Chenab)	June	105.4	107.5	1,211.3	1,416.1	5,599.3	5,392.4
	October	230.4	455.7	1,525.8	1,766.4	5,159.8	4,693.9
BARI (Sutlej & Ravi)	June	102.4	107.5	471.0	542.7	6,878.9	6,802.1
	October	147.5	245.1	514.5	905.7	6,790.4	6,301.5
THAL (Indus & Jhelum)	June	358.4	281.6	716.8	706.6	4,556.8	4,643.8
	October	363.5	327.7	737.3	774.1	4,531.2	4,530.2
DARA JAT	June	522.2	419.1	1,479.7	2,057.9	2,483.2	2,008.1
	October	906.2	1,296.2	1,285.1	1,231.2	2,293.8	1,957.8
SUTLEJ VALLEY	June	491.5	501.5	1,059.8	1,242.0	4,275.6	4,083.4
	October	652.1	871.0	1,649.9	1,675.5	3,525.0	3,280.5
TOTAL FOR PUNJAB	June	1,692.5	1,539.8	6,280.0	7,229.5	25,568.7	24,772.0
	October	2,612.6	3,687.2	6,869.3	7,552.2	24,059.6	22,302.1

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

TECHNICAL NOTE NO. 3

TUBEWELL DEVELOPMENT

INDEX

PAKISTAN

SPECIAL AGRICULTURE SECTOR REVIEW

IRRIGATION AND DRAINAGE

TECHNICAL NOTE NO. 3

TUBEWELL DEVELOPMENT

I. PUBLIC TUBEWELL DEVELOPMENT

Early Tubewell Projects

1.01 Although most tubewell operation in Pakistan is now directed towards using fresh groundwater as a source of supplementary irrigation, public tubewells were initially introduced over 30 years ago as a means of drainage. Public tubewell schemes have since been gradually established for the dual purpose of watertable control and providing additional irrigation supplies.

1.02 Waterlogging and salinity were studied in the Punjab by Schoneman in 1917, by Elsdon in 1921, by Middleton in 1922, and by Wilsdon and Sarathy in 1927-28, who concluded that both canal seepage and rainfall were the cause of rising watertables, with rainfall the major contributor. This led to the first attempt in the region to control waterlogging, in this case by construction of shallow surface drains. In 1940, however, Blench established canal seepage as the major factor in the rise of watertables, and his conclusion may have led to installation of a number of 2 cusec wells adjacent to and spaced at regular intervals along several canals, on the erroneous premise that pumpage would produce an unsaturated zone below the canal and thereby seepage would be reduced. Construction of these tubewells was initiated about 1940, and about 100 wells were installed 60 feet from the canal before careful studies showed that these wells increased canal seepage instead of reducing it. The remainder of the wells (1,227) in this scheme were therefore installed about 600 feet from the water edge to intercept seepage from the canal. They were fitted with horizontal centrifugal pumps mounted just above ground level and were powered by electric motors. About 10 percent of the strainers were wooden or concrete and the remainder were brass. The project was put into operation 1953 when the Rasul power station was installed and the scheme became known as the Rasul Project. It was not particularly successful, but it did lead to the continued use of tubewells to combat waterlogging. The Chuharkana Project was started in 1954, the Jaranwala Project in 1955, Pindi Bhattian in 1958-59, and Chichokimallian in 1960; these involved a total 262 wells with a combined capacity of 464 cusecs. However, their success was limited because the rate of recharge of the aquifer was greater than the pumpage, and so the groundwater level was not effectively lowered.

1.03 A summary of early tubewell installations in the Indus Plain is as follows:

Early Public Tubewell Projects

Name of Scheme	Sites	No. of Tubewells Installed	Approx. Year of Installation	Remarks
1. Amritsar T/W Scheme (for drainage)	Amritsar	15	1911-1917	T/W of 2.0 cusec capacity. By 1936 the Scheme was given up due to low yield of wells.
2. Karol T/W Project (for irrigation)	Karol area near Lahore	20	1938-1940	Designed discharge 1.5 cusecs each. Discharge continued to decrease. By 1960 practically all T/W replaced.
3. Rasul T/W Project (for drainage)	Along main canals in Chaj Doab	405	1947-1954	T/W working in 1961, 313, damaged 142; T/W working in 1967, 285 damaged 186.
4. Rasul T/W Project (for drainage)	Along main canals in Rechna Doab	762	1947-1954	T/W working in 1961, 467, damaged 103; T/W working in 1967, 390, damaged 174.
5. D.I. Khan (for irrigation)	Around D.I. Khan	60	1957	By 1967, only 36 T/W were in operation, five having been closed due to salinity of groundwater.

Of the 1,262 wells installed, only about 720 were in operation in 1967, and of these, 360 have deteriorated, i.e. operating at considerably reduced capacities.

Salinity Control and Reclamation Projects (SCARPS)

1.04 An outgrowth of these attempts was Project 1, a combined fresh groundwater development and drainage scheme, later known as SCARP I. This project, planned by the Irrigation Department with assistance of the U.S.G.S., covered an area of about 1.2 M ac. Its objective was twofold: the control of waterlogging and salinity, and the improvement of agriculture production by maximum utilization of groundwater resources. Finance was obtained from the Development Loan Fund (DLF) of the U.S.A. in February 1959. In accordance with a loan requirement, Tipton and Kalmbach, Inc., U.S.A., became the consultant for this and all later SCARP programs in Punjab, and Hunting-MacDonald in Sind. Construction on SCARP I began in August 1959, and the project became fully operative early in 1963. The project has been successful as regards the control of waterlogging, although the original rather than final designs are sometimes quotes in alleging that the project has not met expectations.

1.05 During the period 1959 to 1963, similar programs for control of waterlogging and salinity by pumping groundwater, and use of fresh groundwater for irrigation and the pumping of saline water to waste, were put in hand by GOP. SCARPS II, III, IV, V and VI were planned for Punjab, and Khairpur, Rohri North and Ghotki for Sind. Completed SCARP projects by construction unit, number of wells installed, and latest pumpage figures are as follows:

Completed SCARP Projects

SCARP or Project	Number of Tubewells	Pumpage in M ac-ft, 1972/73
I	2,067	1.632
II-A	746	1.317
IV		
Mangtanwala	311	0.472
Muridke	624	0.275 /a
III	1,635	0.982
II-B	923	0.193 /a
Mona	138	1.20
Khairpur	540	0.53 /b
Rohri North	566	N.A. /b
Peshawar	28	N.A. /b

/a Low pumpage due to project not being fully operative.

/b Khairpur pumping both saline water to waste and fresh groundwater for irrigation. Peshawar only recently operational, and Rohri North not yet energized.

1.06 In 1964, some wells in the Shadman portion of SCARP I, where the groundwater contained soluble salts in the range of 300-500 parts per million (ppm), deteriorated rapidly in specific yield. Examination of extracted well casings and screens showed that corrosion and encrustation were the principal causes of reduced well yields. As a result of the Shadman findings, procurement of mild stell screens for SCARP IIA ceased. WAPDA and the U.S.G.S. investigated the causes of corrosion and encrustation and the use of alternative materials for screens in Punjab, and Sir Malcolm McDonald and Partners did likewise in Sind. WAPDA decided to consider fiberglass screen for all subsequent SCARPs on a project by project basis. The SCARP II-A donors, the USAID, accepted fiberglass, but the IBRD insisted that some wells on the Khairpur Project be constructed with stainless steel screens. SCARP II specifications were modified to use the 120 mild steel screens on hand and fiberglass for the remainder.

1.07 Construction and commissioning of the wells in SCARPS II, III and IV covered the period 1964 to 1974 with the wells being put into operation as much as 2 years after installation. SCARP IV was reduced in size from 3,273 to 935 wells, owing to intense development of private tubewells in a portion of the area and the lack of local currency to finance an USAID loan. 1/ Khairpur SCARP, begun in 1965, was completed in 1969 and was fully operative by 1970. The Rohri North SCARP began in 1968 and, consisting of 566 wells out of a planned 1,200, was scheduled to be fully operative by June 1974. All these tubewells were provided with slotted fiberglass screens, were gravel packed and fitted with deep well turbine pumps powered by electric motors; well capacities ranged from 2 to 5 and averaged about 4 cusecs. As in the case of SCARP I, as much as two years elapsed between completion of well construction and full operation of these projects, owing to lack of transmission facilities or power. In the Sind, the lack of electric power in the past will be corrected with the completion of the Guddu Power Plant and related transmission facilities.

1.08 In summary, a total of 7,588 public tubewells have been installed in Pakistan, and the projects have largely accomplished the groundwater control objective of the planners. Waterlogging and salinization has been arrested in the SCARP areas, watertables have been or are being lowered, in most instances some damaged land has been returned to cultivation and the irrigation supply has been substantially increased. As a result, cropping intensities have increased but, in general, they have not reached design levels. A disappointing feature in some areas has been dimunition in well yields and an anticipated reduction in the useful life of many wells (see paragraph 3.07).

II. PRIVATE TUBEWELL DEVELOPMENT

2.01 Although farmers have used Persian wheel wells for irrigation for centuries, private tubewell development did not become important in Pakistan until the late 1950s, and then only in fresh water zones to provide water for crops and not to control waterlogging and salinity. The wells were very profitable and consequently were installed at an ever increasing rate until 1967/68 when about 12,000 wells were constructed. The rate of well installations has since decreased to about 4,200 wells for the year 1972/73 1/ and the total was said to be 97,233 at that time. The Ministry of Agriculture claims the rate of installation is now about 3,500 per year. The Provincial

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1/ An USAID loan of about 10 million dollars was cancelled primarily for lack of local currency support.

2/ "Economic Situation and Prospect of Pakistan," 1973, Vol. I.

Agricultural Departments claim that there were about 103,000 wells in Pakistan in August 1972 with 98,409 of them in the Punjab. The mission estimates that there are about 110,000 private tubewells now in Pakistan of which 2/3 are diesel powered and 1/3 are electrified. 1/ Only 7 percent were drilled with modern equipment and the remainder were installed in the traditional labor-intensive fashion.

2.02 No special effort has been made to monitor the areas of private tubewell exploitation, but apparently the rise of the watertable has been arrested in some areas and in others it has been lowered slightly. However, the Gujranwala area, with a heavy concentration of private tubewells has a watertable which is still within 6 feet of the surface over most of the area. 2/ Private tubewells have been profitable and have helped increase crop production in Pakistan; their importance is indicated by the pumpage figures of about 17 Mc ac-ft in the private sector as compared to 7 M ac-ft in the public sector in 1973. 3/

2.03 The public tubewell program appeared plausibly superior to the private, particularly on the basis of a 1965 study by WAPDA covering the Gujaranwala area. In contrast, as regards cost/effectiveness to the Government, the private tubewells have probably been much superior. The WAPDA findings indicated that the size of farm holdings is a serious constraint on the utilization and distribution of water under the private program. About 77 percent of the farm holdings were 12.5 acres or less in size, most of which were fragmented, and two-thirds of these were less than 5 acres in size. Obviously 5 acres, or even 12.5 acres, is not sufficient to fully utilize a tubewell and fragmentation of holdings further complicates the matter. Small landowners can obtain tubewell water by forming a cooperative and operating a well for mutual benefit; by buying water from large land holders; and by installing a well and selling excess water to neighbors. The GOP has encouraged the formation of water-sharing cooperatives but with limited success as illustrated by the data from a survey of private tubewells in 1965/67 in Bari Doab:

1/ Data furnished by WAPDA; Study Volume 2 shows 55 percent diesel, 45 percent electric.

2/ Indus Basin Special Study, Vol. 1. Also see para. 2.05.

3/ Average of various estimates.

Private Tubewells and Farm Size, Bari Doab

Farm Size (Acres)	Tubewell Installations (%)	Number of Holdings Represented (%)	Cultivated Area (%)
Less than 25	12	93	67
25-50	22	6	21
More than 50	66	1	12

This data shows that only 12 percent of the private wells were installed in the smaller holdings which represent 67 percent of the culturable area and 93 percent of the farms. On the other hand, 66 percent of the wells were installed in the largest holdings, which represent only one percent of the owners and 12 percent of the culturable area. Similar patterns were found elsewhere. Obviously a social imbalance exists in the private tubewell program.

2.04 The relation between number of private tubewells and percentage of the culturable area that is served also is important. Data from WAPDA surveys indicated 1/ that from 38 to as much as 78 percent of the culturable area could possibly be served from private sources regardless of number of tubewells and that between only 43 and 53 percent would apply in most cases. The estimate may be low as it was obtained before the rapid increase of private tubewell installation in the late 1960s. Complete service of land by private tubewells is impossible owing to distribution and right-of-way problems and because some farmers will not or are unable to invest in additional irrigation supplies. Publicly developed tubewell projects in fresh water areas, on the other hand, are designed to provide additional water to all commanded lands.

2.05 Gujranwala Tehsil, the most highly developed private tubewell area in the Indus Plains with a CCA of 486,000 ac, in 1967 had 4,534 private tubewells which served only 198,000 ac, or 41 percent of the area. The wells had a pumping capacity of 6,800 cusecs, sufficient to supply the total irrigation requirement of the entire tehsil, or one cusec of capacity for each 71 ac compared to 150 ac per cusec provided in SCARP projects. Nevertheless, in 1968 the watertable was only lowered to within 6 ft of the surface over 55 percent of the tehsil, and 80 percent was within 10 ft of the surface.

2.06 Furthermore, cultivators make no effort to control the watertable level or to reduce salinity with private tubewells; their sole motivation for operating their tubewells is one of profit realizable from a relatively small investment. Thus, control of waterlogging and salinity is left to the public sector.

1/ Regional Plan Northern Indus Plains, Volume 3, p. K-7.

2.07 The costs of the electric power networks required for complete public and private tubewell development in SCARP IV was determined 1/ in 1965. It was found that the power distribution system required for the private tubewell network alone would cost as much as the entire public tubewell development (wells and power distribution works). The power distribution cost could be reduced appreciably by a planned pattern of private wells but even if this were feasible the cost would be considerably higher than equivalent public development.

III. EXISTING SCARP TUBEWELL DESIGN AND CONSTRUCTION

3.01 Tubewells should be designed to supply each watercourse with the amount of supplemental water required for the design cropping intensity, provided this amount does not exceed the long-term recharge. Generally, the design pumping capacity will exceed normal irrigation requirements to provide for "mining" to permit groundwater control during the early stages of development. It should be noted that pumping capacity needs generally to include a safety factor of about 10 percent to allow for the maintenance of pumps and for project flexibility. However, wells are designed for the larger size when the required capacity falls between two available pump sizes. The design operating head of a pump is the sum of the depth to water table plus drawdown, pumping losses and head losses. 2/ For turbine pumps, most of the heads are positive (i.e. are above the pump). For centrifugal pumps all but the lift above pump level are suction heads (i.e. below the pump). The recommended maximum workable suction lift is 20 feet, with a limiting size of pumps to 2 cusecs, and then only for areas where "the watertable is .... projected to decline only a few feet throughout the life of the pump." 3/ Since the drawdown and friction head of a 2 cusec pump approximate 16 feet, such a pump could not be installed at ground level if the static water level was more than 4 feet below land surface. Therefore, 2 cusec centrifugal pumps must be installed below land surface in pits if the watertable is to be lowered significantly below 4 feet. Because of this disadvantage, turbine pumps are preferred for both the Sind and Punjab SCARPS, and the factors in this choice should be studied further by WAPDA.

1/ Tipton and Kalmbach: "Regional Plan for Development."

2/ In the Punjab, it was found that the average drawdown for wells pumping at design discharge ranged from approximately 12 feet for a 2 cusec well to over 22 feet for 5 cusec wells. Pumping losses ranged from 4 feet for a 2 cusec well, to 6 feet for 5 cusec wells. The lift above ground level, averaging about 3 feet, and depth to static water level must be added to these to obtain the minimum operating head.

3/ Regional Plan Northern Indus Plains, Tipton and Kalmbach, Volume 5, pp. 17.

3.02 Initially, it was planned to install one tubewell on each watercourse and locate it near the canal off-take except where watercourses were close together; in these cases a tubewell would be designed to serve more than one watercourse. Later designs attempted to reduce the number of tubewells by increasing their size and connecting two or more watercourses to a single tubewell wherever possible. This reduced the cost of tubewells and the electric distribution system but led to many water distribution and other problems.

3.03 Capital cost is not directly related to the pumping capacity of a tubewell because many of the costs are the same for both large and small wells. The capital cost per cusec of capacity of a 5 cusec well is about 60 percent of that of a 2 cusec well. 1/ It is noteworthy that the capital cost of tubewells, not including electrification, increased only slightly between 1959 and 1968, as shown in the following table. 2/

Construction Costs of SCARP Tubewells

Project	Date of Contract	Number of Wells	Ave. Capacity cusecs	Const. Cost Per Well Rs '000s
SCARP I (Wapda)	1959	782	2.98	42.4
SCARP I Contract	1959	1014	3.04	40.8
Lalian	1962	163	3.52	40.3
Khadir	1964	213	3.90	47.6
SCARP II-A	1964	884	3.72	48.5
Alipur	1965	542	3.71	49.3
Kot Adu	1966	523	3.84	40.4
Mangtanwala	1966	311	4.10	51.8
Muridke	1966	624	3.86	52.1
Rangpur	1967	570	3.92	42.8
SCARP II-B	1968	807	4.10	44.6

Tubewell Casing and Screens

3.04 As stated previously, fiberglass with a minimum wall thickness of 0.18 inches was substituted for mild steel when it became apparent that wells fitted with mild steel screens decreased rapidly in capacity as a result of corrosion and encrustation. 3/ The casing adjacent to the producing aquifer layers was slotted with 10-inch casing having at least 20 square

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1/ Regional Plan Northern Indus Plains, Volume 5, pp. 13.

2/ Tipton and Kalmbach, Inc., Regional Plan, Volume 3.

3/ "Evaluation and Control of Corrosion and Encrustation in Tubewells of the Indus Plain, Pakistan," September 1967, by Clarke and Barnes.

inches of open area per foot of length and the 8-inch casing, 15.75 inches of open area per foot of length. The amount of slotting was based on power at 0.07 Rs/KWH. With the present rate 0.115 Rs/KWH the annual power costs change from about Rs 30 to Rs 59 per ac-ft of water. With the open area of screen per foot of length equal to or greater than the effective aquifer openings per unit of length, the length of perforated casing largely determines the specific capacity of a well. A straight-line relationship does not exist between effective screen length and construction costs, and field trials are required to determine the best design. Most experts agree on the criteria adopted for use in both Punjab and Sind--about 40 ft of screen per cusec of well capacity. The use of mild steel easing needs further investigation in relation to the various conditions in the Indus Basin.

3.05 Disagreement also exists between experts over slot sizes and the proper gradation of the gravel pack and their relation to the grain size of the aquifer material. Slot sizes ranging from 0.03 to 0.12 inches have been used successfully in Punjab. The U.S.G.S. in a report dated August 1972, state: "According to Ahrens criteria the slot size for Punjab aquifers would be 1 to 1.25 mm. or 0.04 to 0.05 inches," and MacDonald et al. recommended a slot width of 0.04 inches for the Lower Indus projects based on the Ahrens method. A slot width of 0.05 inches was used on the Khairpur Project.

3.06 The U.S.G.S. recommend a gravel pack with not more than 15 percent of the gravel coarser than 3/32 inch with a maximum of 1/4 inch. The consultants for the Punjab wells recommend the following:

U.S. Standard Screen Number	Percent Passing Screen
3/8 inch	100
No. 4	65-80
No. 8	25-40
No. 16	0-5

Some experts claim that because of improper packing, excessive amounts of sand are settling in the bottom of the screened portions of wells in Punjab and is reducing well capacity. The number of complete well failures due to sand infiltration has not been high in the SCARPS, and only 33 out of more than 6,000 operating wells, or about 0.5 percent, have been reported.

Material for Screens

3.07 A number of materials have been tested for use as screens. Brass, one of the first used, has not been entirely successful and is very expensive. An unpublished WASID report on performance of 222 brass and 162 mild steel screens in the Shahkot portion of SCARP I constructed in 1961/62 shows, on the basis of tests performed in 1970, that the specific capacity of wells fitted with brass screens decreased 24 percent compared to a decrease of 33 percent for the wells with mild steel screens. In the period 1962/69, 12 brass screens were pulled, presumably because of well failure, as compared to 3 mild steel screens. Also, 10 of 21 brass screens installed in Pindi Bhattian in 1958 decreased 41 percent in capacity over an 8-year period. Of the 60 tubewells installed with brass screens in Dera Ismail Khan and commissioned in 1958, 7 had been pulled by 1968-69; the specific capacity of 38 had decreased an average of 39 percent, and 60 percent of these were in an advanced stage of deterioration. 1/ Despite this, GOP apparently has not yet excluded brass from consideration as a satisfactory material for screens in their program.

3.08 The performance of mild steel screens, which were discontinued in 1964 except in the highly saline drainage wells of the Khairpur Project, has been unsatisfactory except in the Mona and Khadir Schemes and no explanation has been found for this. The performance of fiberglass screens has not lived up to early expectations and reductions in specific capacity have occurred. However, available data indicates that the slots in fiberglass screens are not being plugged, as has been the case with mild steel and brass, but that other factors are responsible. It appears that encrustation of the gravel pack may be the principal factor reducing specific yields of wells having inert screens. Clark and Barnes concluded that active metal (steel, etc.) screens accelerated encrustation and clogging of screen slots under conditions prevailing in the Punjab. Thus, an inert material, such as fiberglass, probably would be better than one subject to corrosion.2/ Other materials that have been suggested and tried for screens include alumimum, bakelitized plywood, polyvinyl chloride and asbestos cement without outstanding success. Further studies of screen materials are needed by WAPDA.

Pumps and Motors

3.09 The choice of pumps is determined by the anticipated pumpting head and the required discharge. For the conditions prevailing in the Punjab (future depth of water table, use of the aquifer as a storage reservoir and anticipated discharge) the best choice seemed to be a water-lubricated vertical turbine type powered by a vertical, hollow shaft, squirrel cage, induction type electric motor. The pump efficiency specified was a minimum of 80 percent at total pump head and 75 percent at a head of 10 feet less. WAPDA stated that the initial wire to water efficiency for the wells in SCARP I was 56 percent, a low value probably reflecting the low pumping heads of the early stages of operation. The performance

1/ Many of the computations of the GOP of this type included only those wells which showed a decrease in specific capacity. The much larger number showing no change or increases were omitted; consequently, the data is biased.

2/ "U.S.G.S. Hydrologic Evaluation of Salinity Control and Reclamation Project" in the Indus Plain, Appendix E, p. 12. "Report of the Special Committee on the working of SCARPS," June 1971, p. 116.

of the vertical turbine pump and its associated auxiliary equipment has been satisfactory and its continued use seems to be justified. In the early stages of the tubewell program, much of the equipment was imported, although turbine pumps manufactured in Pakistan were used in about 700 of the SCARP I tubewells. By the time the contracts for SCARPS II-B and III were let, all of the turbine pumps and all of the motors, except the very largest, and much of the motor control equipment and transformers were being locally manufactured. Accordingly, it does not follow that use of turbine pumps should cease because of importation problems.

IV. AQUIFER SAFE YIELD

4.01 The safe yield of an aquifer is the quantity of water that can be pumped annually without significantly reducing the groundwater level. Thus, the safe yield cannot exceed the long-term mean annual recharge. Withdrawal exceeding recharge (i.e. mining) clearly is necessary in the early stages of most fresh water SCARP operations to lower the watertable to an acceptable level. 1/

4.02 WAPDA calculated in 1972 that the average annual net recharge for the SCARP I area is 2.25 M ac-ft. Data furnished by GOP showed that pumpage from public tubewells on SCARP I, during 1971-1972, was 1.66 M ac-ft, and during this same period, 1,861 private tubewells 2/ pumped an additional 0.64 M ac-ft for a total pumpage of 2.3 M ac-ft. Since there was no change in average depth to groundwater, the 2.3 M ac-ft represents the potential recharge. Therefore, the safe yield is about 1.9 ac-ft per acre GCA. The total recharge of the Punjab was estimated 3/ to be 36.3 M ac-ft for an area of 23 M ac, i.e., 1.57 ac-ft per acre. However, GOP indicated to the Mission that, for planning purposes, tubewell supply should be based on uniform pumpage of 1.2 ac-ft per acre on the gross commanded area. The GOP also stated that this figure was based on past operating experience in SCARP I, a statement seemingly at variance with published data. In any event, it appears excessively low. For future projects, appropriate criteria for safe yield would be determined after analysis.

V. REVISED SCARP DESIGN CRITERIA

5.01 The newly proposed criteria for the design of SCARPS depart radically from those used on the SCARPS already constructed, seem to be

1/ The GOP now proposes mining to 10-15 feet as opposed to the Revelle recommendation of about 50 feet.

2/ The number of private wells varies with source. This number was furnished by field staff.

3/ Massland, Priest and Malik.

unduly restrictive, and do not make sufficient allowance for differences in situations that will be encountered. GOP has indicated, however, that they do not necessarily have to be adopted in all new projects. Present criteria for a portion of SCARP II are as follows. 1/

(a) "Shallow tubewells, 1-2 cusecs should be installed in the sweet water zones, and tubewells capacity 1.5-2.5 cusecs should be installed in the saline zones;

(b) Locally manufactured pipes, brass and coir strainers should be generally used; other types of screens may be used for experimental purposes;

(c) Normally, locally manufactured centrifugal pumps would be used except in special circumstances where local conditions warrant the use of turbine pumps;

(d) For the purpose of planning, criteria for water quality laid down in USDA Handbook No. 60, should be used."

Reference also is made to placing wells on a grid system; the grid is not defined and the intent of this provision is not clear. Furthermore, the watertable is to be stabilized at 10-15 feet below the natural ground surface.

5.02 The basis of the new criteria are not elucidated in documents made available to the Mission, but discussions with GOP and published and unpublished documents indicate the following assumptions have been made by GOP:

(a) Tubewell life is considered to be 12 years, regardless of the type of well or screen;

(b) Imported screen materials are costly and perform no better, if as well as, locally produced screens; coir and brass are specified (although brass is both imported and expensive -- the inconsistency is not explained);

(c) Centrifugal pumps are less expensive than turbine pumps, are more easily serviced and are locally manufactured. (Turbine pumps are also manufactured locally!)

(d) Limiting pump capacities to 2 cusec insures shallow wells that will skim the better quality of water assumed to be available in the upper portion of aquifers.

1/ WAPDA agreement for Engineering Services for Drainage and Reclamation of Saline Groundwater area of SCARP II, January 1974.

(e) The supply from 2 cusec wells combined with available canal supplies constitute the maximum amount of water that the Pakistan farmer can use.

(f) The proposed wells are within the financing and service capabilities of farmers, and therefore the Government would be relieved of the responsibility for operation and maintenance and for amortizing the construction costs.

5.03 GOP officials expressed a strong preference for plans which precluded having more than one watercourse served from a single pump. The Bank recognizes the water management issues and the related socioeconomic factors and the costs and physical problems involved when a pump serves more than one watercourse. It should be noted that generally limiting the size of tubewells in the fresh water zones to 2 cusec will, in most instances, prohibit connecting more than one watercourse to a tubewell. In fact, in some cases it may be necessary to install more than one tubewell on a single watercourse. It is understood that WAPDA can, however, raise tubewell capacities to 3 cusecs on some projects.

5.04 In the saline groundwater areas, the criteria require use of shallow tubewells ranging in capacity from 1 to 2.5 cusecs. There are no operational difficulties which appear to justify small-sized wells for saline groundwater areas, and the least cost solution should govern project design.

5.05 The newly proposed water quality criteria would increase the volume of water to be disposed of and thus compound the already considerable drainage disposal problem. An overall study of drainage problems will be required to determine the amounts that have to be pumped and wasted, and a suitable system for collecting and disposing of the effluent without damage.

Summary of Well Design

5.06 It is concluded that turbine pumps and electric motors performed satisfactorily after protective devices were installed in the motor windings. Mild steel screens have proved unsatisfactory and of short life, and brass is of dubious utility. Most information points toward use of a non-corrosive screen, PVC, fiber glass, asbestos cement or other material, that meets strength requirements and can be properly slotted and installed. Fiberglass met these requirements and accordingly was chosen for the screen material. It has not eliminated reductions in specific capacity but has slowed them down as compared to corrodable materials. Screen slot widths commensurate with the Ahrens or some similar method should be used. A possible deviation might be in the 1 to 1.5 cusec wells where the gravel pack might be eliminated, a strainer substituted for the screen, and slot widths selected to conform to the grain size of the aquifer. The gradation, quality and configuration of the gravel pack, which contribute to well life, should be set by the grain sizes in the aquifer and established methods for determining the gradation should be used. The practice of placing a tubewell at the head of each watercourse should be continued where possible. The newly proposed criteria which limit tubewell sizes to 2 cusecs in the fresh water zones and 2.5 cusecs in the saline water zones specifies centrifugal pumps seem unduly limiting. Centrifugal pumps in the 2 cusecs range will require repositioning in zones of high watertables as the watertable is lowered. Small capacity pumps will increase operator problems and materially increase the cost of an electric power distribution system. The mission reserves judgment on a project plan comprised of only centrifugal pumps until it is compared with alternatives based on sound engineering and viable economics.

OPERATION AND MAINTENANCE OF TUBEWELLS

5.07 Proper operation and maintenance include a trained and competent staff, a workshop capable of repairing the pumps and associated electrical equipment, equipment for well rehabilitation and well servicing, a stock of spare parts and an adequate budget.

5.08 After a project has been constructed and gone through a "running in" period to make it fully operative, WAPDA turns the SCARP over to the Provincial Irrigation Department for operation and maintenance. In SCARP I, the operation and maintenance of the tubewells is vested in an organization charged only with the management of the tubewells. The Khairpur SCARP organization, in 1973, consisted of an engineering wing, an agricultural wing and a cooperatives wing; thus, it seems to have retained most of the organization inherited from the Land and Water Development Board.

5.09 In the Punjab except for SCARP I and one other project, the Irrigation Department has merged the tubewell operation and maintenance functions of the SCARPS with the canal water staff of the area. In effect, the new duties are in addition to the normal responsibilities of operating the canal system; consequently, the tubewells do not get the required specialized attention.

5.10 The mission believes that maintenance of public tubewells schemes requires an organization separate from canal operating staff. This organization should have purchasing and other powers necessary to carry out its responsibilities with despatch and efficiency. The functions of agriculture, credit, cooperatives, etc. can be given to or kept with the respective line departments of the Government.

5.11 The staffing pattern and organizational make-up for both SCARP I and the Khairpur projects, including workshops and spare parts depots, are adequate. The stocks of spare parts were inadequate, however, in many respects as was the case on all SCARP projects.

5.12 Disregarding organizational patterns, the following deficiencies were noted in the operation and maintenance of tubewells:

(a) Budget restraints--probably most important as they are contributory to other shortcomings;

(b) Lack of an adequate supply of spare parts and access to facilities for quick repair and/or replacement;

(c) Excessively long repair and/or down time to replace burned out motors;

(d) The absence of a scheduled pump rehabilitation and/or repair program;

(e) The absence of a well rehabilitation program and an organization for developing and testing well rehabilitation procedures and methods (it is understood that WAPDA are studying this);

(f) The lack of adequate field equipment for servicing pumps and motors.

5.13 Budget constraints have affected project operation and maintenance of projects in Pakistan since development began. The situation with respect to the SCARPS is especially bad because present financing arrangements require heavy outlays of cash from Government with little apparent return. Consequently, only the more pressing and obvious requirements, such as administrative and power costs, are fully funded. The result has been a gradual decline in the mechanical performance of equipment and undue delays in placing tubewells into operation after pump or electrical failures. Project personnel claimed that in most cases spare motors of the size and type required by the project were on hand at all times. If the equipment was at hand, a burned out motor should be restored to service within 48 hours. This is generally not the case, and a week or more may elapse before service is restored. Pump failures understandably require even more than 48 hours for replacement as replacement pumps are seldom available and spare parts are in short supply. Delays in restoring service are critical for they result in considerable crop damage, lack of confidence in the project and build up resistance among the cultivators against tubewell projects. A central purchasing agency has been suggested as a remedial measure which would help, provided sufficient funds were available.

5.14 The decline in tubewell efficiency is another area of maintenance which requires more attention. According to GOP, the average efficiency of tubewells (wire to water) has declined from 56 percent to 36 percent on SCARP I after 10 years of operation. This is equivalent to a 56 percent increase in power necessary to pump the same amount of water. For SCARP I, this means an increase in power costs of about Rs 6 million in 1972-1973. 1/ Put another way, Pakistan is losing Rs 6 million per year because of a decline in pump efficiency on SCARP I alone, and this is approximately equal to the project repair and administration costs for the same year. The efficiency of pumps should be monitored so that a pump rehabilitation program could be implemented in the off seasons, insofar as possible.

5.15 None of the projects had the staff, equipment or the technical knowledge how to conduct a tubewell rehabilitation program. This knowledge must be developed locally, perhaps with outside assistance, before such a program can be initiated. Some methods are available, and it would seem logical to set up an organization in WAPDA to develop the skills and provide the equipment needed for well rehabilitation.

5.16 The fact that returns from projects have been lower than project operating costs has probably contributed to the paucity of O & M funds. Present water rates on SCARPS do not, in many cases, return sufficient revenue to pay the power costs. The following table shows the O & M costs for 1972-1973.

Scheme	No of Tubewells	O & M Millions of Rupees		Pumpage M ac-ft	Cost Per Ac - ft, Rs.
		Power	Total		
SCARP I	2069	17.45	25.62	1.632	15.7
SCARP II A	1260	13.10	18.74	1.317	14.1
Mangtoannwala	311	3.14	4.60	0.472	9.7
Muridke	624		5.31	0.274	19.6
SCARP III	1635		9.45	0.982	9.6
SCARP II B	807		5.34	0.193	20.8

5.17 The Muridke and SCARP II-B unit costs per ac-ft of water pumped are disproportionately high and may be a reflection of the status of project completion, i.e. inoperative tubewells caused by lack of transmission facilities. On the Lalian unit the cost of power alone for one year was Rs 3,766,000 and revenue attributable to the SCARP was Rs 3,278,500. The mission recommends that the rates be adjusted to meet the O & M costs as a minimum.

1/ Statement of O & M charges for completed SCARPS, furnished by GOP, shows power costs of SCARP I as 17.45 million Rs for 1972-73.

VI. CONCLUSIONS AND RECOMMENDATIONS

6.01 Private Tubewells

(a) Private tubewells will not develop the full agricultural potential in fresh water zones. Indications are that up to 50 percent of the command area of the northern Indus Plain will receive tubewell water from private wells if the saline water zones are included.

(b) The probable total cost of private development if electrification is included will exceed the cost of public development. However, the private tubewells are probably superior in cost/effectiveness to the Government.

(c) Private development has contributed greatly to the agricultural production of Pakistan and should be considered as complementary to, rather than a substitute for, the public tubewell program.

6.02 Tubewell Design

(a) Slotted fiberglass casing appears to be the most suitable material for well screens, although other inert materials may prove satisfactory under some conditions and certain types of installation. This matter should be studied further.

(b) Turbine-type pumps are required if the groundwater is to be used as a reservoir and the water level allowed to fluctuate to meet demands during years of insufficient surface supplies.

(c) The material used for gravel packs currently used is not the best quality, and further search for a more suitable material should be made even though such material may cost considerably more.

(d) Use of slot sizes larger than those indicated by conventional methods may have caused sand intrusion problems with presently constructed tubewells.

(e) Centrifugal pumps are usable with limitation regarding depth to watertable and pump capacity, i.e. namely about 4 ft and 2 cusecs.

(f) Projects designed with centrifugal pumps should be compared with a turbine-type installation as an alternative before a final selection is made.

(g) The safe yields of the aquifer in the Punjab will vary slightly from year to year, but for planning purposes it should be taken as 1.7 ac-ft per acre of gross commanded area when groundwater is recirculated for irrigation purposes.

(h) The Pakistan proposal of one tubewell per watercourse using centrifugal pumps needs careful examination and evaluation before adoption for any specific project.

(i) The proposal for limiting the size of tubewells to 2.5 cusecs in saline groundwater areas should be reconsidered.

6.03 Operation and Maintenance

(a) Tubewell projects should be operated by a specialized staff separate from the normal canal operating staff. It need not be separated from the Irrigation Department.

(b) The Government should establish tubewell water rates sufficiently high to recover at least the normal operation and maintenance costs.

(c) A research organization should be established in WAPDA to develop the procedures, methods and equipment required for well rehabilitation. The unit should be structured to train project personnel in well rehabilitation methods. Outside consulting assistance may be required.

(d) Budgets should be provided that permit projects to operate at a high level of efficiency.