PAPER NO. 440

SEVERITY OF WATERLOGGING AND SALINITY PROBLEMS IN PAKISTAN

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SUMMARY

Pakistan possesses the biggest single gravity flow irrigation network on this globe capable of handling over 100 million acre feet of water annually to irrigate an area of about 33 million acres. The irrigation system comprises two large dams, 20 small dams, 20 barrages and diversion weirs, over 40,000 miles of irrigation channels and 90,000 farm outlets. The other redeeming features of this system are a large number of flood protection dikes and embankments and a network of surface drainage. Despite these impressive dimensions of the water system, its economic output per unit of water diverted at the source is perhaps the lowest in the world. There are a number of reasons for such a low economic efficiency of the water system, the most predominant ones being a wide gap between supply and demand of irrigation water, excessive water losses in the system, low irrigation efficiency, inadequate drainage, outdated land and water management practices, fragmented land holdings and the twin menance of waterlogging & salinity.

These and some other minor constraints have been duly recognized but special efforts have been made to evaluate and remedy the twin menace of waterlogging and salinity during the last three decades, and a number of lessons have been learnt from the operation and management of Salinity Control and Reclamation Programme launched in the public sector. Besides engineering, the problem has very strong socio-economic bearings which have added to its complexities . It has assumed

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serious dimensions particularly in view of the exponentially increasing population, deficit in the food production and over-committment of the bulk of water resources to the primitive irrigated agriculture. The key to the attainment of self-sufficiency in food and realization of full productive potential of irrigated lands lies in tackling these problems most effectively within the shortest possible time. The present study evaulates the causes and effects of this problem, up-to-date efforts to reclaim the affected soils and future course of action.

INTRODUCTION

Irrigation in Pakistan has a long history, stretching back to the Indus civilization of over four thousand years. Water diversions on a large scale, however, are relatively recent. Canal Irrigation began on a regular basis at the end of the seventeenth century, primarily to furnish water for the parks and gardens of Mogal royalty. Though the obvious agricultural potential of these canals, most of which could only operate when the water level in the rivers was high, was quickly perceived, farming was by and large still limited to the narrow belts of land around the river banks. Before the beginning of the British era, a number of inundation canals had been built in various provinces of India now constituting Pakistan. According to Michel(1967) these canals were irrigating over four million acres of land in the provinces of Sind, Punjab and the princely state of Bahawalpur by 1857. During this period, the problems of waterlogging and salinity were unknown as there was a hydrodynamic equilibrium between the inflow and outflow of water through the ground water sub-system.

In the mid nineteenth century, the British undertook construction of massive perennial irrigation system that was to make the area called Punjab, the bread-basket of Indian sub-continent. Diversion weirs and barrages were built across a number of rivers to divert water into the irrigation channels both during summer and winter. The new system, though much more reliable in terms of water availability throughout the

year to eliminate droughts, resulted in serious environmental deterioration through flooding, siltation, waterlogging and salinity. It had little control over the river flows and did not have a complementary drainage system. Consequently, soon after commissioning these canals, the level of water in the open wells began to rise visibly and before something could be done, the water table had already arisen to within few feet from the ground surface. Besides reduction in the farm production, waterlogging brought innumerable miseries in its wake. Many towns and villages were abandoned and it became difficult to maintain even the rail and road networks in the affected areas. Stagnant water in the depressions caused spread of Malaria fever which motivated the initiation of investigations and planning to rectify the situation. Observation to record the rate of rise in the ground water level and study of the seepage from the bed and sides of the canals led to the proposal of constructing surface drainage in the irrigated areas. Upto the time of independence, a few canals were lined and 2,300 miles of drains were in operation in those parts of India which became Pakistan. Despite these measures, about 100,000 acres of fertile irrigated lands were going out of commission annually due to the combined attack of waterlogging and salinity at that time. A number of institutional arrangements were also made for investigations and implementation of the remedial measures. None of the symblic measures were, however, intensively purused and extensively applied; and, apart from gaining more knowledge of the problem little in the way of tangible results was achieved.

Since independence, public efforts have been stepped up manifold to match even with this progressively expanding menace. Besides horizontal drainage and lining of some canals, vertical drainage in the form of tubewells were tried ona very large scale. About 12,000 public tubewells and 150,000 private tubewells are already in operation to deflate the rising water table and to supplement the irrigation supplies where the quality of ground water is fit for direct application

or after mixing it with the canal supplies in the area. This has certainly provided some relief.

During the ex-post evaluation of this highly capitalized public sector reclamation programme planned by foreign consultants and mostly executed by foreign contractors, it came to pass that a number of assumptions and design criteria adopted by consultants were highly idealized. Consequently, the project facilities created under this programme did not match the local conditions. This inevitably resulted in shortfalls(1975).

New guidelines were recently evolved for drawing up a multi-objective reclamation programme covering the entire irrigated areas of Pakistan. Simultaneously, a comprehensive master plan for the development of land and water resources is also being prepared which will include proposals for the optimum development of undeveloped resources, conservation and improvement of the efficiency of already developed water resources, flood control and environmental improvement. The success of these plans will depend on the quality of planning critique and financial support and cooperation of the local beneficiaries. It goes without saying that at the present level of technology, attainment of self-sufficiency in food and fibre in Pakistan will depend on the timely completion and optimum management of reclamation programme designed anew which is equally important for the overall economic development also, as agriculture is the mainstay of Pakistan's economy.

CAUSES OF WATERLOGGING

Before the introduction of permanent barrages, diversion weirs and irrigation system, there was a natural balance between the annual precipitation, stream flows, evaporation/evapotranspiration, deep percolation, accretion/depletion of water table, outflow of river water

into the sea and other components of hydrologic cycle. As a result thereof , the water table was shallow only in small areas located above the junctions of various tributaries of Indus. And even here too, there were seasonal variations. During summer, seepage from the rivers pushed up the water table which used to drain out in river channel during periods of low flow in winter. The water table was also comparatively shallower all along the banks of the rivers as compared to the central portion of the land strip where generally it ranged between 75 to 100 feet. Depending upon the nature of the soil there were, however, few exceptions to the above rule, in the form of parched water tables floating over isolated clay lens.

New irrigation developments which took place in the later half of the last century stimulated contemporary developments in the form of rail and road links and other infrastructural facilities. All these activities adversely affected the natural drainage of the flood plains and consequently resulted in frequent ponding up of flood spills from rivers and storm runoff generated by torrential rains. Part of the ponded water evaporated but most of it percolated down to raise the water table. A still higher component of deep percolation came from seepage and leakage from the canals and irrigated fields. The end product was a rapid rise in the water table under the irrigated areas adjoining the river belts. The rate of this upward movement was, however, retarded as soon as the phreatic surface reached within 10 to 15 feet below the natural surface, because part of the percolated water was constantly being pulled up to the surface by capillary action and evaporating into atmosphere.

The above prognosis is the outcome of continued field research and laboratory studies, some of which as recorded by Latif and Shamsi (64) and Harzint (63) are listed hereunder:-

(a) The first action to comprehend this problem and take remedial measures was initiated in 1908, when the government

undertook sub-soil surveys and investigations along the Upper Bari Doab Canal. Following this , a Waterlogging Board was established in 1912 to review the progress of research and development activities . Finding that existing institutional arrangements were inadequate, a Provincial Drainage Board was set up in 1917.

(b) Schonemann examined the results of updated research and investigation carried out by Dyas, Beres-ford, Higham and Kennedy on Upper Bari Doab Canal upto 1917, to correlate rise of water table with the absorpotion losses and seepage.

(c) Elsdon reviewed in detail the correlation between percolation and waterlogging in 1921. He assessed the contribution made by rainfall and leakage /percolation from the irrigation system and expressed his opinion that main cause of waterlogging was the obstruction of subsurface drainage by percolation from large canals.

(d) Middleton conducted extensive studies covering loss of subsurface flow and percolation in 1922 to argue that waterlogging was caused by the insufficient drainage action of rivers and difference in the permeability of sub- strata.

(e) Wilsdon and Sarathi examined the data of water levels in the open wells, rainfall and irrigation application in 1927-1928 to conclude that both rainfall and irrigation were responsible for the rise in water table but the major cause was rainfall.

(f) Blench worked out actual assepage loss in many reaches of Lower Chenab Canal System to discover that seepage

losses from the whole system of main canals and branches ranged between 40 to 47 per cent of the head diversions.

(g) Carlston carried out a comprehensive study of the problem in 1953. He took into consideration all available hydrological and geological data of the affected areas to confirm that canal leakage was the major factor responsible for rise in the water table.

The above studes were primarily directed towards the scientific and engineering aspects of the problem. Taking an overall view of the system, it can be contended that water table has risen to within a few feet of the surface and in some cases it has already reached the top surface in the affected areas due to a number of reasons, the main ones being:

i) Seepage from rivers and irrigation channels.

ii) Flat slope of the natural surface having poor natural drainage.

iii) Unscientific irrigation practices(over-irrigation in some parts and under-irrigation in others) and lack of adequate artificial drainage.

vi) Contribution made by development efforts such as irrigation networks, road and rail links, replacement link canals and other infrastructural developments in the flood plains which have interrupted the seepage of surface runoff at many places resulting into accumulation of ponded waters during monsoon seasons part of which contributes to deep percolation.

Depending upon the soil type and natural topography, all these factors have made their contribution to bring about the present state of waterlogging in Pakistan. Maps showing depth to water table

and water levels for the pre-irrigation period in Punjab and during 1960 were drawn by U.S.G.S.(1967). Being a very convincing visual evidence of rapid rise these are included here as Plate Nos. I and II. The geology and physiography of the soils have been briefly described in Appendix-1.

CAUSES OF SALINITY

As the problems of waterlogging and salinity appreared almost simultaneously and both were equally detrimental to the irrigated agriculture, the causes of the two were also investigated contemporarily. Besides individual efforts, the Land Reclamation Directorate was established in 1922, which set up four research divisions and five experimental and demonstration farms. Later a full-fledged Irrigation Research Institute was established in 1930-31 on the recommendation of a high powered commission on Indian agriculture which after visting some of the affected areas and going through the recorded statistical information on the extent and severity of the problem had come to the conclusion that upto 1928 various organizations which sere assigned this task, had performed, largely, reporting or reviewing functions.

Subsequently, a high powered Land Reclamation Board was also constituted in 1940 with the specific objective of intensifying land reclamation operations in the province of Punjab, but litte was achieved by this organization. This was later replaced by the Soil Reclamation Board in 1952. The activities of the Directorate of Land Reclamation were extended to 12 land reclamation research and experimental stations to cover all possible climatic and geographic conditions. As a result of continued study both in the field and laboratory, following standards were evolved for classification of the deteriorated soils:

Sr.No.	Salt content by Weight of soil	pH Value	Characteristics
1.	Variable	Higher than 9.5	Saline alkali or non-saline alkali soils(Rakkar and Bara type) Difficult and expensive to reclaim.
2.	Above 0.5%	9.0 to 9.5	Saline alkali soil(Mild Rakkar and Bara type). Rather difficult to reclaim.
3.	Above 0.2%	Not exceeding 9.0	Easily reclaimable. Needs copious water supply for leaching.
4.	Lower than 0.2%	8.5 to 9.0	Slightly below normal yield. Needs green manuring.
5.	Lower than 0.2%	Not exceeding 8.5	Good land. Normal crops and yield.

As verified experimentally, following are the main sources of soil salinity:

1) Saline from within the soil

The soil profile of Indus Plains is characterised generally by the presence of sodium salts predominantly of sulphates, chlorides and carbonates. In the northern parts of the Indus Valley, particularly, in the Pubjab area, the predominating salt is sodium sulphate with patches of sodium carbonate whereas the lower part of the Basin, that is, Sind, is impregnated with sodium chlorides. According to some scientists, these salts are remnants of the period when sea extended upto the foot of the mountains in the north(Attock) and these soils were formed as alluvium deposts in the sea water. The other scientistis contend that this salinity has come from the river water itself. It is said that land surface of Pakistan is about 20 to 30 million years old and as a

result of unequal deposition of alluvium, the land surface attained an undulated landscape. Through the action of repeated flooding over million of years, the raised portion of the land remained free of salt but the land in the depressions and adjoining areas where water pools were created, became saline in nature and created almost continuous alkaline patches to a great depth. The uneven distribution of salts is usually apparent as saline and salt-free patches lies side by side. Accordingly, there is a difference in the extent of salinity from place to place and in the nature of salinity.

2) Addition of salt from the irrigation supplies

The salt contents of the river water diverted into the irrigation system in Pakistan range between 100 to 250 ppm, during summer and winter, respectively. The percentage of calcium and magnesium ranges between two to three times that of sodium and potassium. Bicarbonates are higher than sulphates and chlorides. According to an estimate, 25 to 30 million tons of salts are spread annually over the irrigated lands in the Indus Valley through irrigation supplies delivered to the farmland. This works out to roughly one ton of salt per acre per annum. Theoretically, this salt input should balance out partly by the plant use and, partly by leaching process accomplished with river flooding in the areas around the river stream, rainfall and irrigation applications. But in practice, this does not happen in a systematic and planned manner throughout the Indus Basin. As a result, some residual salts are left in patches within the root zone to affect the crop production.

3) Poor irrigation Practices

There are a number of ways in which the poor irrigation practices are aggravating the problems. Some of these are mentioned hereunder:

a) Farm lands are not properly levelled and tirings and quantities of water are not scientifically designed. There is

a seven-day fixed roster of irrigation supplies and whatever water is available in the feeding channel, gets distributed irrespective of the crop requirements. Under the influence of these factors, there is an uneven distribution of water on the farm land which causes patches of saline and non-saline soil profiles. At places where the water depth is more than required, leaching takes place and the soluble salts get leached down through the root zone. At other places where the water depth is thinner than required, the leaching operations are incomplete. Here a part of water which cannot be used by the crop, dissolves the soluble salts present in the soil profile and starts moving downward under the influence of gravity. But before it can go far, it is pulled back to the surface under the influence of capillary action wherefrom it gets evaporated leaving behind the salt concentrations at the ground surface and within the root zones.

b) Salt has also been added on to large tracts of land by the indiscriminate use of ground water of marginal and poor quality for irrigation purposes particularly where the land surface was not properly levelled and quantities of water applied were not sufficient to take care of the evapotranspiration needs as well as leaching requirements to clear the root zone of the excessive salt build-up.

4) Salinity as a by-product of waterlogging

As water table came close to the top surface, the water loss through upward movement of water through capillary action and evaporation from the surface increased. Through this process, the soluble salts present in the ground water as well as in the soil through which this upward movement took place moved upward through the soil profile and added to salt concentration within the root zone as well as at the surface.

5) Salt from hill torrents

Areas in the vicinity of foot hills of salt range mountains in the northern parts of Indus Basin are receiving, year after year, a regular dose of saline spills, which is adding to the salinity problems in the affected areas.

6) Improper land use

It has been noticed that plots of saline land subjected to different types of land use end up differently in matter of soil salinity and response to agricultural practices. Compared to a cultivated plot, fallow lands permit more quickly the upward rise of the salts, specially in the areas of shallow ground water.

Summing up, it can be said that soil salinity in Pakistan is a product of climatic conditions, original soil chemistry, land use, irrigation practices and depth to water table. In deltaic plains and coastal areas, small peripheral areas are also being affected through salt intrusion through sea waves travelling into the interior. Plate III shows salinity of ground water.

7) Effect of different levels of Salinity

a) Growth and yield of the crops

Broadly speaking, following crop responses have been witnessed:

Range of E.C. (in mmhos/cm at 25° C)	Crop Response
0 to 2	Salinity effects mostly negligibe
0 to 4	Yields of very sensitive crops may be restricted.
4 to 8	Yields of many crops restricted.
8 to 16	Only tolerant crops yield satisfactorily.
Above 16	Only a few very tolerant crops yield something.

(b) On the germination of crops

Germination of wheat, rice, corn, barley, gram and cotton is adversely affected at the moisture level equal to 15 per cent of the holding capacity. This effect is intensified when sodium chloride concentration is above 0.2 per cent. However, higher rate of germination even at 0.4 per cent sodium concentration can be obtained by increasing the moisture level upto 45 per cent of the field capacity in case of wheat, barley and maize and 90 per cent in case of rice. Similar results can be obtained in case of grams and cotton with 75 per cent moisture level at 0.3 per cent sodium chloride concentration. In case of sugarcane, 50 to 100 per cent inhibition of sprouting has been observed at seven atmospheric pressures, corresponding to an E.C. of 8.6 mmhos/cm (1970).

EXTENT OF THE PROBLEM

Although the problem was progressively increasing ever since it appeared during the early part of this century, it was takne more seriously after independence for a variety of reasons some of which are mentioned below:

(1) The goals and objectives of the new nation were more explicitly defined to put the agriculture development and self-sufficiency in food and fibre at priority No.1

(2) Migration of population from India resulted in rapid rise of population.

(3) India laid her claim on the three eastern tributaries of Indus which were irrigating over six million acres of fertile land in Pakistan.

To match even with the situation, a number of practical steps were taken to stop further spread of this menace upto 1952. These

included:

1) Frequent and extensive canal closures.
2) Lowering of canal water levels.
3) Conversion of areas from perennial to non-perennial irrigation.
4) Lining of irrigation channels.
5) Planting of eucalyptus groves.
6) Reclamation by rice cultivation.
7) Application of additional water supplies in selected areas for leaching down salts.
8) Reclamation by the application of green manure and chemicals to the affected areas.
9) Limited use of open surface drains and ground water pumpage by tubewells.

None of these measures were, however, applied intensively or extensively and apart from gaining greater knowledge of the problem, little in the way of tangible results could be achieved. The assessment of the situation led to the decision that scale of efforts have to be stepped up manifold. International assistance was sought in this context and scientific investigations and studies were initiated in 1953 under Colombo Plan. This included aerial photography and field confirmation to get data on land forms, soils, land use and salinity and waterlogging. It was completed in 1955 on an area of 71 million acres. A geological investigation was also carried out simultaneously in the southern zone and in Baluchistan region. As a result of these studies, Government of Pakistan published a comprehensive report on land forms, soils and land use in Indus Plains by February(1958) which gave the extent of area affected by waterlogging and salinity. Table-I has been drawn up accordingly:

On the publication of above information, a serious controversy arose on the definition of the terms waterlogging and salinity, as it applied to the local setting. It was the considered opinion of some experts

TABLE-I

Gross Area (Thousand acres)	Predominantly poorly drained or water-logged (thousand acres)		Predominantly severely salined (thousand acres)		Area in which saline patches are common (thousand acres)	
1	2		3		4	
	Area	Percentage	Area	Percentage	Area	Percentage
46511.6	11,310	24.3	4,820	10.4	11,150	24.0

Note: In column 4, figures do not include areas tabulated in column 3.

that land should be declared as waterlogged where the water table was within 0 to 6 feet from the natural surface and normal crop production was not possible. Likewise, there was difference of opinion on the chemical composition of the soil which should be declared as salinized. Consequently different sets of statistical figures became available. One of these figures is presented in Table-II which is based on the data collected by the Land Reclamation Directorate, Lahore and reported by Directorate of Soil Survey(1978).

TABLE-II

Year	Total area Survyed (million acres)	Salt-affected area		Waterlogged area	
		Million acres	Per cent	Thousand acres	Per cent
1961-62	34.69	5.27	15.2	84	0.24
1962-63	37.69	5.61	14.9	196	0.52
1964-65	36.97	5.44	14.7	249	0.67
1966-67	37.47	5.47	14.9	197	0.57
1967-68	38.06	5.47	14.3	209	0.55

Apparently, there are wide variations in the two tables for which besides definition of the problem, a number of other factors are also responsible. These are:

(i) Total area surveyed in the two studies is different.

(ii) By 1958, extensive surveys and investigations were in hand but no effective remedial measure had been implemented to check the further spread of these problems as well as to reclaim the affected areas.

(iii) During 1960s, an all-out effort was made in the public sector to install deep tubewells as well as a network of surface horizontal drains. A contemporary development in the private sector in the form of small capacity tubewell not only supplemented the existing water resources but also supported the efforts to eliminate waterlogging and salinity.

(iv) There was a wet cycle during 1950s which substantially aggrevated the problem of waterlogging in Pakistan upto 1958. This was followed by a dry cycle during 1960s which automatically resulted in a drop in the water table.

(v) The data collected by WAPDA through its Ground Water and Reclamation Division was based on extensive coverage of the Indus Basin. In Contrast, the Directorate of Land Reclamation was primarily a provincial organization based in Punjab and its sphere of activities was gradually extended to other provinces in 1955 when all these provinces were merged into a single administrative unit called West Pakistan. Therefore, the quality of the two data was not comparable.

FRESH DATA COLLECTION

It was realized during the evaluation of completed projects that reconnaissance survey conducted by Colombo Plan Survey Project, Directorate of Land Reclamation, Punjab, Directorate of Soil Survey of Pak-

istan, Water and Soil Investigation Division of WAPDA and Messrs. Hunting Technical Services of U.K. were not comprehensive enough to apply modern planning concepts for the preparation of appropriate projects for salinity control and reclamation. Based on the lessons learnt from the the past experience, new guidelines were evolved for drawing up a comprehensive master plan for the entire irrigated areas in Indus Basin. As an essential part of this effort, complete data on soil salinity and ground water fluctuation is being collected systematically on scientific basis. The programme of data collection has been designed to meet the following objectives:

1) To monitor changes in the waterlogging and salinity problem since the previous surveys of 1960s.

2) To establish reliable benchmark data for future monitoring efforts.

3) To provide reliable base for investigation, planning and development of land and water management projects including salinity control and reclamation projects throughout the Indus Basin.

Physical Progress in Data Collection

A French firm Messrs. Institute Geographique National(IGN) has carried out synchronized panchromatic black and white infra-red aerial photography during 1976. The results obtained have been compared with the previous aerial photography undertaken during 1953-65. In addition, field surveys have been completed over 21 million acres by now and the remaining 20 million acres of the irrigated area will be covered by June 1981. During the field surveys, about 0.13 million soil samples and about 5,000 water samples were collected which were analysed in the laboratories located at Lahore, Mona and Hyderabad. The results of all these studies are being compiled to prepare six different types of interpretative maps at a scale of 1:250,000. These maps would show:

(a) Surface salinity.

(b) Soil profile chemical conditions

(c) Water table depth(soil saturation zone).

(d) Water quality.

(e) Soil Classification

(f) Land Use.

The result of surveys and investigations completed so far in respect of surface salinity, profile salinity and water table depth have been compared in the following tables with the coresponding values derived from earlier surveys:

SOIL SALINITY AND WATER TABLE SURVEY AREA OF

21 MILLION ACRES IRRIGATED AREA OF INDUS BASIN **

SURFACE SALINITY

Area Surveyed	Period	Salt Free	Slightly Saline	Moderately Saline	Strongly Saline	Misc. Landtype
		PERCENT				
Overall 21 million acres	1977-78	67	12	8	10	3
	1953-65	5	18	11	16	2

PROFILE SALINITY*

Area Surveyed	Period	Non-saline Non-sodic	Saline	Non-saline Sodic	Saline Sodic	Missing Data
		PERCENT				
Overall 21 million acres	1977-78	60	9	4	26	1
Punjab 12 million acres	1977-78	77	4	5	13	1
	1953-65	48	4	24	23	1

WATER TABLE*

Area	Period	Watertable depth				Misc.
		0-3'	3-6'	6-10'	10'	Landtype
		PERCENT				
Overall 21 million acres	1977-78	6	16	23	53	2
Punjab	1977-78	6	12	19	61	2
12 million acres	1953-65	2	12	25	59	2

* Old data of profile salinity and watertable for Sind and Baluchistan not available.

** Source - A Report on Project-wise soil Salinity and Water Table Survey Data - issued by WAPDA Master Planning & Review Division during November 1978.

While a true picture will emerge when the entire surveys and field studies have been completed by June, 1981, it appears from the above comparison that vertical drainage in the form of tubewells has resulted in reclamation of salt affected areas through the process of leaching. At the same time, the studies carried out by the Central Monitoring Organization as well as Directorate of Soil Survey(1973) have shown that indiscriminate use of ground water is resulting in secondary salinization of the root zone at a number of places. This process of slow-poisoning can be detected by a very minute study which is not possible under the extensive surveys of the entire Indus Basin being carried out at a macro saale by the Master Planning wing of WAPDA. This apprehension is well-founded as even previously, wide variations were detected between the results of the overall surveys when compared with detailed investigations for specific projects as well as post-project monitoring of already completed projects. Therefore, the results of the current surveys have to be taken only as a general

frame of preference rather than sacrosanct basis for project preparation.

ACTION PROGRAMME

As discussed earlier, a number of scattered steps were taken to control the upward movement of water table and salinziation of fertile agricultural lands in a few localities. While it was considered desireable to restrict the flow of water in the irrigation system to lower the water table, additional water was pushed into the system for reclamation of the saline lands by leaching down of the injurious salts accumulated on the surface or in the root zone. Most of these steps were applied on a limited scale upto the mid 50s which did not produce any appreciable results. In the later part of 50s when Water & Power Development Authority(WAPDA) was created primarily to execute replacement works included in the Indus Waters Treaty with India, it became possible to plan and implement remedial measures for the entire Indus Basin. A chronological overview of various actions taken so far is presented here.

Reclamation Plan 1961

The extent of the problem and the progress of remedial measures was reviewed in a high powered conference presided over by the President of Pakistan. During this meeting it was reported that 11.3 million acres area was waterlogged, 11.1 million acres was partially affected by salinity and five million acres severely affected by salinity. It was also stated during this meeting that about 100,000 acres of fertile irrigated land was being lost annually due to the spread of waterlogging and salinity in the Indus Basin. The situation was viewed very seriously and a directive was issued that WAPDA should prepare a comprehensive salinity control and reclamation programme for the entire Indus Basin. At that time, the field investigations and surveys had not been completed for the entire Basin but still a reclamation programme based on whatever data was available was prepared hurriedly. This plan was carried to Washington by President Ayub Khan in July 1961 and discussed with Presi-

dent Kennedy who not only gave financial aid for the execution of this programme but also deputed a team of experts to visit Pakistan and review the programme prepared by WAPDA. The recommended reclamation programme included 26 tubewell and drainage projects costing about US $ 1,200 million to be completed in 10 years ending 1971. Later on this programme was reviewed by a number of international experts including U.S. White House Panel of Experts on Waterlogging and Salinity headed by Dr. Roger Revelle, Messrs. Tipton & Kalmbach, an engineering consulting firm engaged by WAPDA for planning, designing and implementation of salinity control and reclamation projects, Messrs. Harza Engineering Co. of Chicago who were general consultants of WAPDA for various works including preparation of a master plan for the water and power resources of Pakistan, World Bank team headed by Dr. Peter Lieftinck and Messrs. Hunting Technical Services and Sir McDonald & Partners of U.K. Each of them presented their own development strategies but there were only minor differences in the overall approach, planning concepts and design criteria for project facilities. The programme took off very well as the first project was planned, designed, implemented and put into operation strictly according to schedule. This was Salinity Control and Reclamation Project-I covering an area of 1.2 million acres in the northern parts of Indus Basin where 2,041 deep public tubewells were progressively put into operation by March,1963. However, the pace of executing subsequent projects was retarded by a number of uncertainties about the geohydrological parameters, financial constraints, lag between the installation of tubewells and their energization and non-fulfilment of the objectives by the projects already completed and under operation.

Basic Approach of Reclamation Plan

An FAO report prepared for a seminar on waterlogging and salinity during 1964 highlighted the salient features of the basic approach as under:

by a World Bank team of experts headed by Dr. Peter Lieftinck which submitted a report on 'Development of Water and Power Resources of West Pakistan' in 1967. They assessed the situation on the basis of earlier surveys and investigations, various reports issued by the WAPDA consultants & specific sample studies carried out by another group of international consultants called Irrigation and Agriculture Consultants. In their final report, the reclamation programme has been evaluated in the context of overall development of land and water resources of Indus Basin with particulare reference to ground water development. Briefly, their conclusions were as under:-

i) An overall 'Action Programme'for land and water development was proposed as shown in the table given below. The provision on Irrigation and Drainage works represents 23 percent of the total public sector costs of the proposed programme:

Public Development Expenditures for Proposed 'Action Programme' 1965-75 (Million Rs.)

Tarbela Dam	3,862
Other Surface Storage Projects-Raised Chashma	116
Sehwan	22
Manchar	
Surface Storage Investigations	115
	4,115
Irrigation and Drainage Project	
On-going public tubewell schemes	991
Proposed New Public Tubewell Schemes	1,563
Canal Remodelling and Other Irrigation Schemes	1,002
Surface Drainage	900
Tile Drainage	223
Investigations	431
Flood Protection	149
Miscellaneous	25
	5,284
Agriculture	
Fertilizer Subsidies	1,200
Plant Protection Subsidies	800
Extension and Research	440