

WAPDA Programme of Waterlogging and Salinity Control for West Pakistan

By

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Introduction

In order to bring about conditions which would lead to a healthy prosperous agriculture, the need for waterlogging and salinity control has come to be recognized as one of the fundamental requirements for the irrigated areas of West Pakistan.

In the extensive irrigated lands which constitute about 85% of the overall 39 million acres cultivated annually, the wide incidence and rapidly increasing rate of waterlogging and salinization, has assumed such large proportions that the predominantly agricultural economy of the Province is greatly threatened. When it is considered that the present agricultural production is not even adequate to meet the basic food requirements of the people, the decline in agricultural productivity due to loss of land and diminishing yields brought about by waterlogging and salinization, poses a problem which has become all the more serious in the face of a rapidly increasing rate of population growth.

With no readily available alternate means to offset the declining productivity, it has become imperative to rehabilitate the presently irrigated lands so as to increase their productivity from the present low level which is hardly 30 to 40 percent of their full potential.

To achieve this objective, however, is not an easy task. The planning of effective waterlogging and salinity control measures requires protracted and extensive studies and the execution of the required works involves mobilization of vast financial and other resources. In West Pakistan waterlogging and salinity control measures will be required over the entire 33 million acres of irrigated lands, and this calls for a concentrated effort according to a set programme of action.

History of Early Action

The history of the waterlogging and salinization of the irrigated lands in West Pakistan and a review of the measures which have been adopted to deal with this problem have been covered in other papers presented at this

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symposium. The salient features which emerge from this resume are that although the seriousness of the problem was fully realized from the earliest times, the measures which were adopted from time to time were for the most part half way measures and were neither extensively applied nor intensively pursued. The result was that no substantial improvement could be brought and the extent of the waterlogging and salinity continued to grow to unmanageable proportions. No concentrated effort was made to establish the most feasible means to solve the overall problem and then to determine what would be required in terms of investigations, engineering works or finances, so that a programme of action could be launched. These aspects have been developed only recently.

Investigational Requirements

Before any reclamation works can be undertaken, it is necessary to clearly define the causes of waterlogging and salinization. All factors which have a direct bearing on the reclamation techniques and can lead to the design of the necessary physical works, must be evaluated. In 1954, a comprehensive programme of investigations was launched in the irrigated areas of the Upper Indus Plains. These investigations included the compilation and analysis of historic ground water level data; an extensive and frequent programme of ground water level observations; compilation and analysis of precipitation and stream flow records; a programme of exploratory drilling to depths of 600 feet on an average to determine geologic conditions and hydraulic properties of the water bearing materials; drilling of tubewells for conducting aquifer tests; soil classification and salinity surveys; canal leakage studies; chemical analysis of surface waters and ground waters at varying depths; and other related investigations.

A similar programme of investigations was also started in the Lower Indus Plains in 1959 by the WAPDA.

These investigations have been completed to a considerable extent and they have furnished a basis on which further action on waterlogging and salinity control measures can be initiated with full confidence and with a reasonable assurance of the results that can be anticipated.

Reclamation Approach

As a result of the many years spent on research and investigation of the waterlogging and salinity problems, and, more recently, on the planning and construction of reclamation projects, considerable knowledge of the problem and of feasible means of reclaiming waterlogged lands has been gained. The salient elements which have evolved from this knowledge and which point the way to the ultimate solution of waterlogging and salinity problem of West Pakistan are :

1. Water must pass through and below the root zones of plants to prevent the accumulation of salts and to leach out salts which are already present in the soil or have accumulated as a result of irrigation. There thus must always be a downward flow of water past the root zones of the crops. This requires a substantial increase in the amount and rate of application of irrigation water over that heretofore applied in many areas, particularly in the Upper Indus Plains.
2. It is not economically feasible to attempt to eliminate or materially reduce seepage losses from canals of the existing irrigation systems. Certain new canals now under construction are being provided with linings, but in general it has been found that lining of existing canals on a sufficient scale to affect the problem is not practical or economic.
3. The incremental recharge of the aquifer resulting from deep percolation of water applied to the lands and from canal seepage in most areas is greater than the rate which water can flow out of the aquifer to downstream areas and hence, unless withdrawn from the aquifer, will cause water tables to rise. Not only did this incremental recharge cause water table to rise to their present levels, but all lands which are irrigated will inevitably become waterlogged and ultimately go out of production unless appropriate drainage facilities and reclamation measures are undertaken.
4. Waterlogging can be overcome by means of tubewells, which pump ground water from the aquifer over a considerable depth of aquifer, or by deep open drains which take in ground water mainly from the upper layers. The choice of method, or combination of methods, of drainage to be used is affected by the particular physical characteristics of the area and by economic considerations. In some areas, particularly in the Upper Indus Plains, providing tubewells to remove the incremental recharge to the ground, water combined with appropriate surface drainage works for the removal of storm water, form the most feasible means of lowering ground water tables to create the drainage opportunities necessary for effective reclamation. In other areas shallow surface drains are all that is necessary or desirable, particularly in the large predominantly rice-growing areas of the Lower Indus Plains which are irrigated only in the Kharif (summer) season. The system of rice cultivation generally practised involves

frequent changing of the water on the fields leading to high surface run-off, while evapotranspiration from natural vegetation and 'dubari' crops (grown with residual soil moisture) in the Rabi (winter) season, serves to depress the water table before the next irrigation period. The network of shallow drains can be used as disposal channels for more drastic leading on special reclamation areas. In perennial areas water applications are slightly lower, but the water table is not drawn during the Rabi season to the same extent and deep drainage, whether by tubewells or open drains, is necessary where waterlogging exists or threatens. Only by deeper drainage can crops other than rice be brought to high yields.

5. In areas where the ground water is of acceptable quality tubewells, aside from providing a means of obtaining adequate drainage and reclaiming lands, can supply an important supplemental source of water for irrigation. Ground water supplies that can be made available for irrigation by means of tubewells are of about the same order of magnitude as present canal supplies in some areas, thus making it possible to greatly augment water supplies at less than the cost of providing the equivalent amount of water that could be made available by any other means. Where quality of ground water is suitable for irrigation use, all such ground water supplies can be fully utilized under existing irrigation systems. Where the quality is not suitable for direct irrigation use, the water can be disposed of into drains or into large canals and diluted with larger volumes of good quality river water for use in downstream areas.
6. In many areas the best method of exploiting ground water for use as a supplemental irrigation supply is by so situating the tubewells as to permit them to deliver the water into the smaller channels of the irrigation system or directly into water courses (farm ditches), thus making available, together with the canal supplies, a much larger volume of water for irrigation use without the necessity of increasing the capacity of the larger canals of the existing systems.
7. The process of lowering of ground water table, when accomplished by means of tubewells, provides opportunity to use the tremendous underground reservoir to store excess water in years of high runoff and high precipitation for later use in years of deficient runoff and precipitation. Such storage is particularly valuable as it is not subjected to losses and, where its water quality is

satisfactory, it can be made available near its point of use. Where the deep ground water in the Lower Indus Plains is not usable, deep surface drains afford a solution, the water being removed only from the upper layers and the lower very saline water being left undisturbed.

Programme of Reclamation

Based on the results of investigations and by following the principles enunciated above it was possible for the first time to formulate fairly well defined proposals in regard to the measures which must be adopted for waterlogging and salinity control in West Pakistan.

Soon after its inception in 1958, The West Pakistan WAPDA, which was given the responsibility for undertaking reclamation works, took full advantage of the results of investigations and started on a programme of waterlogging and salinity control by initiating a major project covering an area of 1.2 million acres. Keeping the magnitude of the problem in view, it was proposed by the WAPDA that Reclamation operations should be carried out on a continuing basis so as to reclaim 1 million acres every year, and with this object another Project covering an area of 2.2 million acres was formulated in the Upper Indus Plains and 2 Projects covering 700,000 acres in the Lower Indus Plains.

In early 1961, the Planning Commission took full cognisance of the waterlogging and salinity problem and by taking into consideration the need for the development of additional irrigation supplies as a necessary adjunct for reclamation, estimated that an expenditure of Rs. 55,000 million will be required if adequate relief was sought from the grave consequences of waterlogging and salinity in West Pakistan. This estimate by the Commission highlighted the fact that the control of waterlogging and salinity, on which the whole future of the agricultural prosperity of West Pakistan is based, will be a protracted process and will call for an enormous investment. To review this problem and to launch a concentrated attack on it, the President of Pakistan called a High Level Conference in April, 1961 in which it was decided that the West Pakistan WAPDA, along with an overall appraisal of the magnitude of the waterlogging and salinity problem in West Pakistan, should prepare a programme of waterlogging and salinity control and determine the magnitude of resources which will have to be mobilized to undertake the programme in a period of 10 years.

The WAPDA drew up such a programme, and this was accepted by the Government of Pakistan. The salient features of this programme are described under suitable heads below :

Scope of Reclamation Programme

Investigations have revealed that there are no large contiguous irrigated areas which may be free from waterlogging and salinity, or where the natural drainage conditions may be such that no waterlogging or salinity problems could be anticipated. Moreover, none of the measures which have so far been carried out have resulted in the permanent reclamation of any sizable areas. It is, therefore, necessary that all the irrigated areas be provided with proper physical means to reclaim and protect the agricultural lands. The WAPDA programme extends to all such irrigated areas in the Upper and Lower Indus Plains, covering about 33 million acres, with the exception of 2.5 million acres in the Lower Plains following at a later stage.

Reclamation Works

In order that the Reclamation Works, could be planned and executed effectively, it has been proposed to sub-divide the irrigated areas into Project Units. These units have been conceived by taking into account all the regional factors which have a direct bearing on the nature and type of works which would be required, so that each project unit represents typical conditions for which typical solutions are needed. These project units vary from relatively small to quite large projects areas. On the basis of the available data and for the purposes of planning and establishing priorities some of the larger projects have been divided into sub-units. At the time of detailed planning it will be necessary to sub-divide the remaining project units into sub-units so that the required rate of progress could be achieved on the execution of works and treatment of areas.

The location of the various project units as per programme is indicated on Plate I from which it will be seen that the Upper Indus Plain has been divided into 10 units covering 22.4 million acres and the Lower Indus Plain into 16 sub-units covering 10.6 million acres.

The physical works required for the reclamation of waterlogged and salinized land in each project unit have been conceived in conformity with the principles stated earlier, taking into account the nature of the problems of each area, their topographic, geologic, and hydraulic characteristics including quality of ground water supplies, climatic conditions, crops, canal supplies and all other relevant factors which have a bearing on the selection of the most feasible means of reclamation. In most areas where investigations have been completed, the nature and scope of the works could be accurately determined on the basis of detailed schemes prepared for generally similar areas. In areas where field investigations were still in progress and in areas where little field data was available, the reclamation works were conceived as far as possible on the basis of general geologic and hydrologic characteristics.

An abstract of the principal reclamation works, conceived for the

different project units in the Upper and Lower Indus Plains, is shown in Tables 1 and 2 respectively.

Special Aspects of Reclamation Works

From the abstract of the project works it will be observed that in the 22 million acres of the Upper Indus Plains the principal method of drainage is by the use of tubewells. In the Lower Indus Plains this method has been allowed for also, but surface drains will be provided in rice areas.

The choice of tubewells is based on the results of the programme of groundwater investigations in both the Upper and Lower Indus Plains. The investigations in the Upper Indus Plains have indicated that most of the irrigated area of about 25.9 million acres of the total surveyed area of 27.3 million acres is underlain to depths of 1000 feet or more by unconsolidated alluvial sediments which are saturated to within a few feet of the land surface. The sediments range in texture from medium sand to silt, clay but the sandy sediments predominate, and test wells have shown that tubewells yielding 5 cusecs can be developed virtually at any site. Quality of water studies have brought out that over an area of 18.1 million acres out of which 16.1 million acres lies within the irrigation command the salt concentration of the ground water to an average depth of 500 feet is less than 1750 p.p.m., so that with dilution with canal supplies, the ground water can be easily utilized for irrigation. Under the balance of the irrigated areas in the Upper Indus Plains the ground water has salt contents exceeding 1750 p.p.m. and going as high as 20,000 p.p.m. The extent of such areas which occupy compact zones in Lower Central portions of the doabs is, however, small.

These conditions coupled with the recharge potential make the utilization of ground water a feasible proposition and in view of the present inadequacy of irrigation supplies for crop needs and leaching, tubewells achieve a dual objective—drainage as well as development of irrigation. However, it will also be necessary to pump saline ground water and dispose it. The extent of such ground-water pumpage will be small and with dilution with large river flows even this ground water will add to the useable supplies in the downstream areas.

In the WAPDA Programme, the ground water withdrawal for the Upper Indus Plains was taken as 18.7 million acre feet (M.A.F.) for irrigation-cum-drainage and 5.8 M.A.F for drainage. With the additional ground water supply for irrigation it was projected to meet the optimum crop water requirements and to convert most of the non-perennially irrigated areas into perennial areas.

Auxiliary Works

Apart from the reclamation works described above the programme of waterlogging and salinity control also requires the provision of adequate electric

TABLE
Areas, Works, and Costs

| Project Priority No. | Project Name | Gross Commanded Area (1000 Acres) | Culturable com-manded Area (1000 Acres) | Tubewells for Irrigation and Drainage | | |
|----------------------|------------------|-----------------------------------|---|---------------------------------------|-------------------------------|-----------------------------|
| | | | | Total Cost | | |
| | | | | No. | Foreign Exchange (1000's Rs.) | Local Currency (1000's Rs.) |
| 1. | Central Rechna | 1,200 | 1,100 | 1,796 | 42,600 | 49,500 |
| 2. | Chaj | 2,300 | 2,100 | 3,250 | 1,400 | 46,700 |
| 3. | Lower Thal | 1,000 | 900 | 2,400 | 79,000 | 39,200 |
| 4. | Upper Rechna (a) | 1,500 | 1,400 | 1,755 | 65,600 | 31,600 |
| 4a. | Lower Rechna | 2,600 | 2,000 | 2,580 | 84,700 | 42,200 |
| 5. | Southern Bari | 2,400 | 2,300 | 2,800 | 91,900 | 45,700 |
| 5a. | Upper Thal | 2,000 | 1,600 | 3,630 | 119,500 | 59,300 |
| 5b. | Bahawalpur | 4,000 | 3,500 | 1,505 | 49,500 | 24,600 |
| 6. | Northern Bari | 4,400 | 3,700 | 5,075 | 166,600 | 82,900 |
| 7. | Right Bank Indus | 1,000 | 900 | 2,425 | 82,400 | 41,300 |
| Total | | 22,400 | 19,500 | 27,216 | 863,200 | 463,000 |

(a) Includes 190 miles of surface flood drains to be constructed in Central

No. 1

Upper Indus Plains

| Tubewell for Drainage | | | Surface Flood Drain | | | Total Capital Cost | |
|-----------------------|-------------------------------|-----------------------------|---------------------|-------------------------------|-----------------------------|----------------------------|------------------|
| Total Cost | | | Total Cost | | | Equivalent Rupees (1000's) | Per acre CCA Rs. |
| No. | Foreign Exchange (1000's Rs.) | Local Currency (1000's Rs.) | Miles | Foreign Exchange (1000's Rs.) | Local Currency (1000's Rs.) | | |
| — | — | — | — | — | — | 92,100 | 84 |
| 61 | 2,900 | 1,100 | 450 | 3,800 | 48,100 | 184,000 | 88 |
| — | — | — | 210 | 1,900 | 22,400 | 142,500 | 157 |
| — | — | — | 520(a) | 4,800 | 55,600 | 157,600 | 112 |
| 415 | 19,100 | 7,500 | 900 | 7,600 | 96,200 | 257,300 | 128 |
| — | — | — | 720 | 6,200 | 77,000 | 220,800 | 96 |
| 353 | 14,800 | 6,200 | 370 | 3,300 | 39,600 | 242,700 | 152 |
| 2000 | 65,700 | 32,700 | 800 | 7,100 | 85,500 | 265,100 | 76 |
| 648 | 30,000 | 11,700 | 1830 | 15,700 | 195,600 | 502,500 | 135 |
| — | — | — | 190 | 1,400 | 20,300 | 145,400 | 161 |
| 3,477 | 132,500 | 59,200 | 5,990 | 51,800 | 640,300 | 2,210,000 | 113 |

Rechna Doab.

TABLE 2
Areas, Works and Costs—Lower Indus Plains

| Project Priority No. | Project Name | Gross Commanded Area (1000's ac) | Culturable Commanded Area (1000's ac) | Deep (1000's GCA ac) | Method of Open Drains Reclamation (1000's GCA ac) | Drainage Surface (1000's GCA ac) | Tubewells Drainage (1000's GCA ac) | Foreign Exchange (1000's Rs.) | Local Currency (1000's Rs.) | Total Capital | |
|----------------------|--------------------|----------------------------------|---------------------------------------|----------------------|---|----------------------------------|------------------------------------|-------------------------------|-----------------------------|----------------------|-----------------------------|
| | | | | | | | | | | Cost in (1000's Rs.) | Equivalent Per Acre CCA Rs. |
| 2a | Khairpur | 565 | 525 | 219 | — | — | 354 | 35,800 | 44,000 | 79,800 | 152 |
| 2b | Gaja | 127 | 115 | 127 | — | — | — | 13,600 | 20,800 | 34,000 | 300 |
| 3a | Larkana-Shikarpur | 504 | 442 | — | 75 | 429 | — | 9,100 | 15,000 | 24,100 | 55 |
| 3b | Tando-Bago | 341 | 314 | 341 | — | — | — | 35,000 | 56,100 | 91,100 | 290 |
| 4b 1 | Shahdadkot-Manchar | 1915 | 1613 | 116 | 347 | 1452 | — | 80,000 | 151,000 | 231,000 | 143 |
| 4b 2 | Thatta | 118 | 108 | 118 | — | — | — | 12,100 | 18,700 | 30,800 | 285 |
| 4c 1 | Pinyari-Guni | 652 | 600 | — | 253 | 399 | — | 15,600 | 27,200 | 42,800 | 72 |
| 4c 2 | Kashmore-Jacobabad | 1482 | 1363 | — | 238 | 1244 | — | 27,400 | 47,600 | 75,000 | 55 |
| 4c 3 | Guni-Fuleli | 332 | 305 | — | 165 | 167 | — | 8,200 | 16,800 | 25,000 | 82 |
| 5b 1 | Sakro Jam | 206 | 190 | — | 63 | 143 | — | 3,800 | 6,200 | 10,000 | 53 |
| 5b 2 | Ghotki | 947 | 788 | — | — | — | 947 | 19,100 | 10,500 | 29,600 | 37 |
| 5b 3 | Jati Badin | 337 | 310 | — | 159 | 178 | — | 9,400 | 15,000 | 24,400 | 79 |
| 5c 1 | Ochito | 62 | 57 | 62 | — | — | — | 5,700 | 8,400 | 14,100 | 250 |
| 5c 2 | Fuleli East | 320 | 294 | — | 160 | 160 | — | 8,000 | 17,800 | 25,800 | 88 |
| 6a | Pat | 250 | 225 | — | 125 | 125 | — | 8,000 | 12,500 | 20,500 | 91 |
| 6b | East Nara | 2457 | 2210 | 1000 | 1457 | — | — | 181,000 | 267,000 | 448,000 | 204 |
| Total | | 10,615 | 9,459 | 1,983 | 3,042 | 4,297 | 1,301 | 471,800 | 734,600 | 1206,400 | 127 |

power generation, transmission and distribution facilities for the operation of the tubewells. These requirements have been determined and incorporated in the programme. It is estimated that for the completed programme, 800,000 K.W. of power will be required and the annual energy consumption would be of the order of 2,100 million K.W. The transmission and distribution of this power will also require a major undertaking as the necessary facilities would have to extend over an area of 22 million acres.

Cost of the Programme

Based on the level of prices current in 1961 and considering the nature and extent of the works that would be required, estimates of capital cost have been worked out for the various projects and sub-projects and also for the power generation, transmission and distribution facilities. According to the estimates the reclamation works under the Programme would cost Rs. 3,400 million and the power system another Rs. 2,500 million making a total of Rs. 5,900 million. For the reclamation works, the summaries of the principal physical works embodied in each project, the areas benefited and their costs as divided into expenditures in local and foreign currencies are shown on Tables 1 and 2 for the Upper and Lower Indus Plains, respectively. The capital cost per acre of culturable commanded area benefited is also shown in these tables for the various projects. From these tables it will be seen that the total cost of the reclamation works in the Upper Indus Plains is Rs. 2,210 million with a foreign exchange component of 47%, and for the Lower Indus Plains it amounts to Rs. 1,206 million with a foreign exchange component of 39%. On the average the cost of the reclamation works for the Upper Indus Plains comes to Rs. 113 per acre C.C.A., and for the Lower Indus Plains Rs. 128 per acre C.C.A.

The breakdown of the power system costs for the two regions are shown in Table 3 and amount to Rs. 2,423.5 million of the Upper Indus Plains and Rs. 76.5 million for the Lower Indus Plains.

Costs and Benefits

In order to determine the financial feasibility of the various projects incorporated in the Programme their annual costs as well as the benefits to be derived therefrom have been determined.

The annual costs of the reclamation works as determined, include the operation and maintenance charges and also fixed charges representing amortization of the capital and depreciation. The fixed charges have been worked out by amortizing the capital cost of the tubewells in 20 years and that of the surface drainage works in 40 years, allowing 4 percent interest. The depreciation has been considered by the provision of a sinking fund to cover the replacement cost of the tubewell pumps and motors during the initial 20 years and for the entire cost of the tubewells during the next 20 years period.

TABLE 3
Estimated Expenditure on Power Generation, Transmission and Distribution
in Million of Rupees

| | Generation and Primary Transmission | | | Secondary Transmission and Distribution | | | Total | | |
|--------------------|-------------------------------------|-------|-------|---|-------|--------|---------|-------|--------|
| | Foreign | Local | Total | Foreign | Local | Total | Foreign | Local | Total |
| Upper Indus Plains | 796 | 404 | 1200 | 769 | 454.5 | 1223.5 | 1565 | 858.5 | 2423.5 |
| Lower Indus Plains | 20 | 5 | 25 | 33 | 18.5 | 51.5 | 53 | 23.5 | 76.5 |
| Total | 816 | 409 | 1225 | 802 | 473 | 1275 | 1618 | 882 | 2500 |

With these criteria the fixed charges substantially remain the same throughout the period of 40 years. The operation and maintenance charges have been determined according to the needs of the various projects.

In accordance with the foregoing the annual cost of the reclamation works will be of the order Rs. 400 million. This cost is equivalent to an overall cost of Rs. 14 per year per acre benefited. For the various reclamation projects the annual costs are shown in Table 4. In relation to the Capital Cost, these annual costs range from 9 to 15 percent.

To evaluate the programme in monetary terms the gross value of the crop production that can be obtained with reclamation has been estimated and compared to that corresponding to the average production of the area under waterlogged and salinized conditions. This study indicates that with reclamation the increased value of crops raised in a single year will be more than the capital cost of the reclamation works. For the various projects the annual increase in the value of crop production has been determined separately taking into account the cropping patterns and the cropping intensities, which can be achieved with improved conditions and with the availability of additional water supplies. The additional farm costs to achieve the increased level of production have then been taken into account to determine the annual increase in farm income. Table 5 shows this increase, the corresponding annual cost of the Reclamation Works, and the net increase in annual farm income for the different projects, in total amount, as well as per acre of cultureable commanded area. From the Table it will be seen that the net increase in Farm income per acre C.C.A. amounts to an average of Rs. 64 for the projects in the Upper Indus Plains and Rs. 58 in the Lower Indus Plains.

TABLE 4

Annual Cost

(Million of Rupees)

| Project Priority No. | Project Name | Fixed Costs | Operation and Maintenance | Power | Total (rounded) |
|----------------------------|-------------------------|----------------|---------------------------------|-------|--------------------|
| Upper Indus Plains | | | | | |
| 1 | Central Rechna .. | 5.6 | 1.8 | 8.9 | 16.3 |
| 2 | Chaj .. | 10.2 | 3.3 | 9.8 | 23.3 |
| 3 | Lower Thal .. | 8.1 | 2.3 | 8.5 | 18.9 |
| 4 | Upper Rechna .. | 8.7 | 2.0 | 7.5 | 18.2 |
| 4a | Lower Rechna .. | 14.1 | 3.4 | 18.7 | 36.2 |
| 5 | Southern Bari .. | 12.2 | 2.1 | 10.0 | 25.3 |
| 5a | Upper Thal .. | 13.7 | 3.9 | 18.5 | 36.1 |
| 5d | Bahawalpur .. | 14.7 | 3.8 | 12.5 | 31.0 |
| 6 | Northern Bari .. | 27.6 | 6.5 | 32.9 | 67.0 |
| 7 | Right Bank Indus .. | 8.2 | 2.3 | 8.4 | 18.9 |
| | Sub-total .. | 123.1 | 32.4 | 135.7 | 291.2 |
| Lower Indus Plains | | | | | |
| 2a | Khairpur .. | 3.845 | 2.826 | 2.372 | 9.0 |
| 2b | Gaja .. | 1.675 | 1.161 | .002 | 2.8 |
| 3a | Larkana-Shikarpur .. | 1.167 | .894 | .053 | 2.1 |
| 3b | Tando Bago .. | 4.350 | 3.127 | .214 | 7.7 |
| 4b 1 | Shahdadt-kot-Manchar .. | 10.610 | 6.821 | .238 | 17.7 |
| 4b 2 | Thatta .. | 1.500 | 1.049 | .018 | 2.6 |
| 4c 1 | Pinyari-Guni .. | 2.090 | 1.470 | .055 | 3.6 |
| 4c 2 | Kashmore-Jacobabad .. | 3.530 | 2.667 | .147 | 6.3 |
| 4c 3 | Guni-Fuleli .. | 1.210 | .863 | .018 | 2.1 |
| 5b 1 | Sakro-Jam .. | .495 | .360 | .015 | .9 |
| 5b 2 | Ghotki .. | 1.440 | 1.042 | 1.230 | 3.7 |
| 5b 3 | Jati-Badin .. | 1.186 | .850 | .025 | 2.1 |
| 5c 1 | Ochito .. | .695 | .498 | .035 | 1.2 |
| 5c 2 | Fuleli East .. | 1.253 | .944 | .074 | 2.3 |
| 6a | Pat .. | .999 | .727 | .035 | 1.8 |
| 6b | East Nara .. | 21.000 | 15.270 | 1.085 | 37.3 |
| | Sub-total .. | 57.045 | 40.569 | 5.616 | 103.2 |
| | Total (rounded) .. | 180.1 | 73.0 | 141.3 | 394.4 |

TABLE 5

Increase in Farm Income

| Project Priority No. | Project Name | Annual increase in Farm income* (1,000's Rs.) | Annual cost of Reclamation Works (1,000's Rs.) | Net Increase in Annual Farm Income | |
|---------------------------|-------------------------|---|--|------------------------------------|---------------------|
| | | | | Per Project (1,000's Rs.) | Per CCA Acre Rupees |
| Upper Indus Plains | | | | | |
| 1 | Central Rechna .. | 92,500 | 16,300 | 76,200 | 69 |
| 2 | Chaj .. | 178,500 | 23,300 | 155,200 | 74 |
| 3 | Lower Thal .. | 77,000 | 18,900 | 58,100 | 65 |
| 4 | Upper Rechna .. | 114,500 | 18,200 | 96,300 | 69 |
| 4a | Lower Rechna .. | 171,000 | 36,200 | 134,800 | 67 |
| 5 | Southern Bari .. | 179,000 | 25,300 | 153,700 | 67 |
| 5a | Upper Thal .. | 165,000 | 36,100 | 128,900 | 81 |
| 5d | Bahawalpur .. | 199,000 | 31,000 | 168,000 | 48 |
| 6 | Northern Bari .. | 281,500 | 67,000 | 214,500 | 58 |
| 7 | Right Bank Indus .. | 77,000 | 18,900 | 58,100 | 65 |
| | Total .. | 1,535,000 | 291,200 | 1,243,800 | Av. 64 |
| Lower Indus Plains | | | | | |
| 2a | Khairpur .. | 42,800 | 9,043 | 33,757 | 64 |
| 2b | Gaja .. | 6,820 | 2,838 | 3,982 | 35 |
| 3a | Larkana-Shikarpur .. | 51,390 | 2,114 | 49,276 | 111 |
| 3b | Tando-Bago .. | 30,630 | 7,700 | 22,930 | 73 |
| 4b 1 | Shahdadt-kot-Manchar .. | 133,110 | 17,669 | 115,441 | 72 |
| 4b 2 | Thatta .. | 8,540 | 2,567 | 5,973 | 55 |
| 4c 1 | Pinyari-Guni .. | 53,560 | 3,615 | 49,945 | 83 |
| 4c 2 | Kashmore-Jacobabad .. | 119,840 | 6,344 | 113,496 | 83 |
| 4c 3 | Guni-Fuleli .. | 22,570 | 2,091 | 20,479 | 67 |
| 5b 1 | Sakro Jam .. | 12,950 | 870 | 12,080 | 64 |
| 5b 2 | Ghotki .. | 46,740 | 3,112 | 43,028 | 55 |
| 5b 3 | Jati-Badin .. | 25,020 | 2,061 | 22,959 | 74 |
| 5c 1 | Ochito .. | 4,070 | 1,228 | 2,842 | 50 |
| 5c 2 | Fuleli East .. | 19,510 | 2,271 | 17,239 | 59 |
| 6a | Pat .. | 17,990 | 1,761 | 16,229 | 72 |
| 6b | East Nara .. | 57,600 | 37,355 | 20,245 | 9 |
| | Total .. | 653,140 | 103,239 | 549,901 | Av. 58 |

*After deducting increased farm production costs.

Considering the programme as a whole the cost to benefit ratio works out to 2.25:1 as shown below :

| Item | Upper Indus Plains | Lower Indus Plains | Total |
|---|--------------------|--------------------|----------|
| (million of rupees per year) | | | |
| 1. Gross value of crop production after reclamation .. | 5,058 | 2,403 | 7,461 |
| 2. Gross value of crop production prior to reclamation .. | 2,666 | 1,320 | 3,986 |
| 3. Gross value of incremental crop production .. | 2,392 | 1,083 | 3,475 |
| 4. Annual cost of reclamation programme .. | 291 | 103 | 394 |
| 5. Increased costs of production after reclamation .. | 857 | 318 | 1,175 |
| 6. Total Costs .. | 1,148 | 421 | 1,569 |
| 7. Benefit: Cost Ratio (item 3/item 6) | 2.1 : 1 | 2.6 : 1 | 2.25 : 1 |

Quite apart from being adequately justified from the financial point of view, the Programme of Reclamation has other advantages. The reclamation works will provide the physical means of greatly increasing agricultural production, even beyond that which was attained prior to the time the lands became affected by waterlogging and salinity. Not only will such works restore the original drainage capabilities of the lands but in many areas, particularly where tubewells are provided, will also provide a substantial quantity of new water to supplement existing canal supplies. In other areas, the improved drainage will permit utilization of supplemental surface water supplies, which supplies cannot be effectively utilized until the affected lands are adequately drained. Another tangible benefit accruing from the programmes will be the opportunity to reduce foreign exchange expenditure for the importation of food. Pakistan has been importing food at rates in excess of 800,000 tons per year for the past several years. It is estimated that with the control of waterlogging and salinity, overall food production from presently irrigated lands can be increased by at least 15 million tons per year. Other indirect benefits will accrue from construction of the projects. The construction of electric distribution facilities to supply power for the tubewells and villages within the area will lead to a much higher standard of living and greatly enhance opportunities for the

development of agricultural industries. Improvements in diet and health that will result from the increased food production and elimination of waterlogging cannot be evaluated precisely in monetary terms. However, the improvement in diet will be substantial. Elimination of swampy areas will reduce considerably the opportunity for flies and mosquitoes to breed, and can be expected to lower the incidence of water-borne diseases.

Review and Subsequent Modifications

The WAPDA programme of 1961 presented for the first time a broad picture of the waterlogging and salinity problem in West Pakistan. It brought out that technically and economically feasible means could be adopted to deal with the problem. The programme was not intended to be the final word on future reclamation development. It was to be refined and modified after further investigation and study.

Following the release of the WAPDA programme, the problem of waterlogging and salinity control has been re-examined by two independent groups. The U. S. President's Science Advisory Committee released a draft report of the waterlogging and salinity problems of West Pakistan in September, 1962 in which the salinity problems and other factors limiting agricultural production have been evaluated. WAPDA has recently completed an appraisal of the resources and potential development of West Pakistan.

The report of the U. S. President's Committee presents a plan for raising agricultural production by removing the limiting factors and by making optimum use of the available water and land resources. Waterlogging and salinity control is considered to be a part of this plan. The report outlines the general principles and approach that should be adopted, but does not contain a detailed programme of works by project units. Apart from suggesting ways and means for overcoming economic, and social problems related to agriculture, the report emphasises maximum development of the water resources for irrigation by full use of the available ground water to intensify cultivation, to leach salts, to lower the high water table, and to achieve a greater reliability and regulation of the water supply.

For the Upper Indus Plains the report estimates that, if the watertable is lowered to 100 feet depth over a period of 30 years, the amount of groundwater that could be pumped annually would be 46 million acre feet. Of this amount, 36 million acre feet would be available for crop use after allowing for losses and saline groundwater disposal. This compares with 24 million acre feet presently available for crop use from the canals.

For the lower Indus Plains, the report brings out that there is not as much scope for increasing irrigation supplies as in the Upper Indus Plains, because most of the groundwater is saline. Furthermore, a considerable area is used

exclusively for the rice cultivation and there are areas where drainage with tubewells is not practicable.

Although the financial implications of the proposal of the U. S. President's Committee have not been presented, an estimate for the capital costs has been indicated for the Upper Indus Plains. The per-acre capital costs are estimated to be Rs. 119 for tubewells, electrification and drainage, and Rs. 60 for power. According to the WAPDA programme, these costs were estimated at Rs. 113 and Rs. 108 respectively.

A further study has been carried out by WAPDA on the conjunctive use of surface and ground water. This study was made in connection with the preparation of the Master Plan for developing of water and power resources of West Pakistan.

It has become evident that the concept and direction of the Salinity Control and Reclamation Program should stress water-supply and land-use aspects—not merely salinity and waterlogging; and that the total cost of the expanded program now envisioned will exceed greatly the original reconnaissance cost estimates.

The reclamation program presently under consideration anticipates construction of reclamation and salinity-control works for about 11 million acres in the Northern Zone and 6 million acres in the Southern Zone between 1963 and 1975. Although the construction rate will not be entirely uniform, an average of about 2500 tubewells is expected to be completed annually. Necessary corollary programs of surface-drainage improvements and canal remodelling will be accomplished to keep pace with tubewell construction.

Companion programs of canal- and distribution-system construction will be carried on in the Taunsa, Gudu, and Ghulam Mohammad commands and to a lesser extent in other commands. The proposed salinity control and reclamation program, as determined under the Master Planning programme is based on meeting specific 1975 needs, in addition to starting projects that will not be in full operation until after 1975, but which will be needed subsequently.

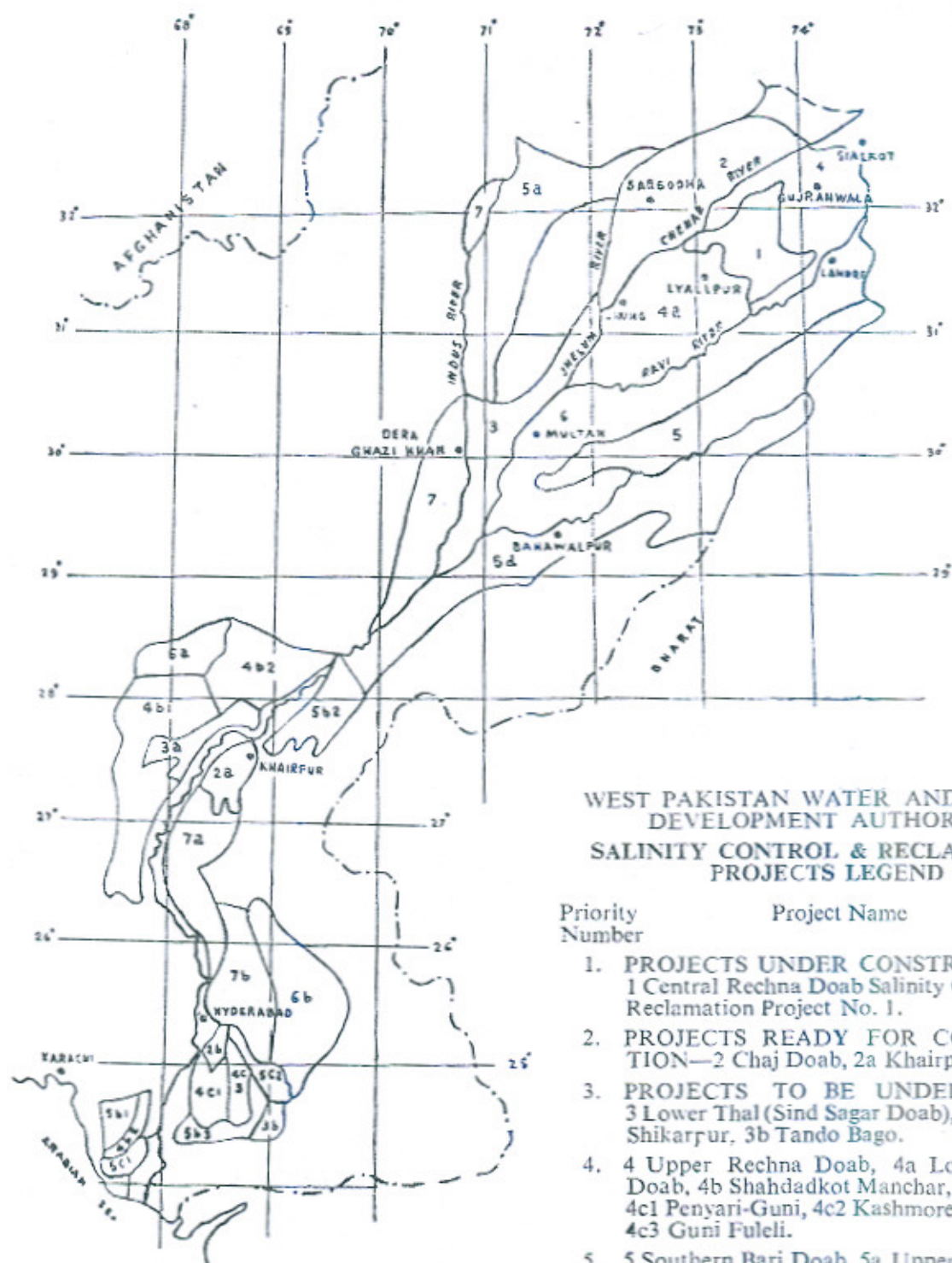
The salinity control and reclamation program must, of course, be continued after 1975 until it covers all of the lands in the Indus Plains and other parts of West Pakistan where such improvements can be physically accomplished and economically justified.

The physical size of the area to be covered by salinity control and reclamation projects prevents the uniform execution of reclamation improvements. However, as the U. S. President's Committee concluded, the most effective use can probably be made of prospectively-available technical guidance and funds by undertaking, successively, units of approximately one million acres. These units should, wherever possible, include all or major portions of canal

commands. The actual boundaries and sizes of these projects and the sequence for their undertaking will be established by regional-planning programs.

Close co-ordination and co-operation is required of the Planning Commission, WAPDA, the Irrigation Department, the Agricultural Development Corporation, the Ministry of Food and Agriculture, the Soil Reclamation Board, general and project consultants, other technical advisory groups, and financing institutions, if the construction and agricultural production goals are to be reached. Achievement of the necessary teamwork among the agencies and individuals involved will be a major effort in view of the current division of authority and responsibility.

Development of plans and overall co-ordination of construction for development of West Pakistan's water and power resources—particularly the programs for the Indus Plains—will be the responsibility of WAPDA. The combined forces of WAPDA and its consultants have a broadly based capability in the planning, design and construction of large civil works projects. Construction will also be undertaken by other government agencies, but such construction may not prove wholly effective unless it fits with master, basin and area development plans. Layouts of canals, drains, roads and bridges must be considered together and in relation to project conditions as a whole, if rational and economic plans are to be prepared for the development of areas. In addition to pre-construction planning, it will be necessary to develop operating plans for integrate use and distribution of surface and ground-water supplies, as well as plans for operating tubewells in the period immediately following construction.



WEST PAKISTAN WATER AND POWER
DEVELOPMENT AUTHORITY
SALINITY CONTROL & RECLAMATION
PROJECTS LEGEND

- | Priority Number | Project Name |
|-----------------|---|
| 1. | PROJECTS UNDER CONSTRUCTION 1 Central Rechna Doab Salinity Control and Reclamation Project No. 1. |
| 2. | PROJECTS READY FOR CONSTRUCTION—2 Chaj Doab, 2a Khairpur, 2b Gaja. |
| 3. | PROJECTS TO BE UNDERTAKEN—3 Lower Thal (Sind Sagar Doab), 3a Larkana Shikarpur, 3b Tando Bago. |
| 4. | 4 Upper Rechna Doab, 4a Lower Rechna Doab, 4b Shahdadkot Manchar, 2b Thatta, 4c1 Penyari-Guni, 4c2 Kashmore Jacobabad, 4c3 Guni Fuleli. |
| 5. | 5 Southern Bari Doab, 5a Upper Thal (Sind Sagar Doab), 5b1 Sakro Jam, 5b2 Ghotki, 5b3 Jati Badin, 5c1 Ochito, 5c2 Fuleli East, 5d Bahawalpur. |
| 6. | 6 Northern Bari Doab, 6a Pat, 6b East Nara |
| 7. | 7 Right Bank Indus, 7a Rohri North, 7b Rohri South. |

PLATE 1