The Programme of Investigations in the former Sind

By
A. P. S. FORBES*
AND
G. R. HOFFMAN*

INTRODUCTION

The former Sind Region includes fourteen million acres of gross commanded area, irrigated from the three Indus barrages at Gudu, Sukkur and Kotri. Round the northern and western perimeters of the irrigated area are piedmont lands watered by sailaba** irrigation from the numerous hill torrents which discharge their flood waters into the plain. Agricultural productivity throughout the whole region is extremely low; salinity and waterlogging are present over large areas; and the majority of the cultivators are existing at well below what should be regarded as subsistence level.

There is an urgent need to obtain substantial increases in agricultural productivity as soon as possible and to control the rising watertables and spreading salinisation of the soils. However, it would be folly to attempt to deal with the problems piece-meal, treating different areas in isolation. A first essential is an overall plan for the whole Region, integrated with a similar plan for the complete Indus Basin, so that early construction projects can be pressed forward without the danger of their conflicting with others which might later be shown to be more profitable.

The investigation programme in the Sind Region which started in a small way in 1960 and was expanded in 1963 is aimed at producing a preliminary development plan for the whole area by mid 1965. In such a large area having some particularly difficult problems to be solved this is a very short time indeed. In these circumstances it has been necessary to consider carefully how best to carry out the investigation so that the recommendations will not require appreciable changing as a result of information which will be obtained from subsequent more detailed studies.

This paper sets out the main objectives of the investigation programme and gives a general appraisal of the studies which are being carried out. As the work proceeds, all aspects are kept continuously under review and modifications are introduced in the light of further informations obtained. The programme itself is flexible but the objectives remain fixed.

---

*Hunting Technical Services and Sir M. MacDonald and Partners.

**Irrigation by diversion from intermittent streams.

OBJECTIVES

The main objective of the present investigation is the production of an overall plan for the optimum agricultural development of the Lower Indus Plain. In order to be able to draw up such a plan, it is necessary to have information on a number of different aspects which will be considered under the three main heads of Water, Land and Farming. The objectives under each of these may be summarised as follows :

1. **Water.**
   - (*a*) To make recommendations for the full development of all possible sources of additional water in the area, including ground-water, surface storage and hill torrents.
   - (*b*) To produce an overall plan for the allocation of available water supplies throughout the area.
   - (*c*) To determine drainage and flood protection requirements and the best systems to adopt in the different parts of the area.
2. **Land.**
   - (*a*) To determine the status of the land with regard to texture fertility and salinity of the soil and the depth of water-table.
   - (*b*) To establish the present land use.
3. **Farming.**
   - (*a*) To assess the factors which at present limit agricultural production.
   - (*b*) To make broad recommendations on improved methods for achieving maximum output.
   - (*c*) To draw up an overall plan for cropping in the region.

Several of these objectives are inter-related; for instance the allocation of water supplies throughout the area must depend on the relative fertility of the land and also on the recommended cropping in the different parts of the region. In fact, throughout the whole of the studies this inter-dependence of the different aspects must be fully appreciated and allowed for by continuous co-ordination of the results being achieved by the various investigation teams.

To reach these main objectives detailed studies are necessary and these are outlined in the following paragraphs :

STUDIES TO BE UNDERTAKEN

In accordance with the sub-division set out in the previous section, details of the necessary studies will be considered under the heads of Water, Land and Farming. The following summary is not intended to be exhaustive, nor will all the subjects mentioned necessarily be studied. As the work proceeds, some which have been started may be dropped and others which appear to be more important may be started. Only in this way can we ensure that the information necessary for the decisions to be made in the final recommendations is obtained.

1. Water

In the Indus plains one of the main limitations on the expansion and intensification of agriculture is the shortage of water in the River at particular times of year. Studies under this head concentrate on determining what water is available, and how it can be most efficiently used. They are considered under nine sub-headings as follows :

(*a*) Meteorology

Variations in climate, rainfall intensities, storm patterns and movement, and the usual observations of humidity, evaporation, wind speed, sunshine hours and solar radiation are being studied at a number of stations set up throughout the Region. Past records from existing meteorogical stations in or near the area are being collected and analysed. It is anticipated that some 20 to 30 climatological stations will be set up in the Region over the period of the investigations.

The data will be used in evaluating the variation of effective rainfall, in consumptive use calculations for the water requirements of crops and in assessing the surface run-off for calculating drain capacities.

(*b*) The River Indus

The River is the life line of the whole region and a full understanding of the hydrology, geo-hydrology, soils and land use of the area between the bunds is of paramount importance, especially in so far as the winter water for the Ghulam Mohammad areas is concerned. When it is appreciated that all the Indus water that reaches Sukkur during the winter months is diverted into canal systems at the barrage and no water passes down the river bed, the full importance of river regeneration from the riverain areas and river recharge to possible tubewell schemes is realised. In between the bunds in selected areas there is also a flourishing farming community from periods during the year and much more must be learnt of the local land use and whether output can be increased.

A preliminary general study will be made after collecting all available information on the river discharges and abstractions, historical and recent river course changes, extent of flooding and bund construction and data available from longitudinal sections. At the same time studies of the regime of the water table in the riverain areas will be undertaken by means of observation pipes at several cross sections. Methods of gauging and flow measurement will be checked and chemical and physical analysis of river water at selected sites will be taken at monthly intervals. Once a quarter a sample from each site will undergo a complete chemical analysis for the indentification and assessment of salts. A soil, land use and farming study will be undertaken of the area between the bunds and a survey will be made of the bunds after the

rains to establish their present condition and investigate the possibilities of using the loop bunds for storing water at peak flood period.

(*c*) **Geo-Hydrology.**

The main object is to study the overall geology and ground-water hydrology of the Indus Basin South of Kashmore. Specific aims are to determine as accurately as possible the distribution and extent of fresh ground-water, to assess the potential yield for irrigation and to establish the feasibility of tubewell drainage in areas in which waterlogging is becoming a limiting factor to productive farming. Special aspects which will come under review will be the effects of corrosion and incrustation on tubewell screens and casing. The salinity of aquifer water will also be determined for suitability for irrigation and more will be learnt of the aquifer constants and of the formation grading of the aquifers. These studies are being undertaken in close co-operation with the Water and Soils Investigation Division of WAPDA.

In addition to the drilling work, studies are also being carried out on the water-table levels throughout the region. Networks of subsoil water level pipes already exist over extensive areas. These pipes are being checked and selected lines of pipes used for readings at regular intervals to study seasonal water-table fluctuations. Where no observation pipes already exist a limited number are being installed. Additional information on water-table depths is obtained from the soil survey teams. As complete a picture as possible of the behaviour of the water-table throughout the Region is thus being built up.

(*d*) **Hydrology.**

In order to assess the rates of run-off from rainfall in these irrigated areas, where the excessively flat gradients and pattern of field bunds effectively reduce normal surface flow, field studies are being put in hand to take observations on actual run-off in specific catchments. Heavy storms will be studied, taking meteorological observations in conjunction with the meteorological section. Ground-water level variations, soil mositure changes, infiltration rates, and changes in volume of water stored in depressions will be measured, the latter by successive photographs taken from the air, supplemented by measurements on the ground.

Using informations from the other sections on crop water requirements, cropping patterns, canal losses, effective rainfall, etc., calculations of overall water balance will be made to determine the net ground-water recharge or drainable surplus in the different parts of the Region for use in the design of drainage systems.

(*e*) **Irrigation.**

One of the main objectives of this Section is to gather information on how the various canal systems of the Region operate at present. Arising out

of this is the broad determination of how far existing cultivation is limited by unequal distribution of supplies. Comprehensive studies of the irrigation system which have already been started in parts of the Sukkur barrage command in 1961 are being extended. Design details of the major canals will be compared with present performance by means of field and office studies, using discharge and level observations.

Information on cropped areas for each season in major distribution units will be used to prepare irrigation intensity maps from which actual water distribution may be deduced and compared with design.

In the Gudu and Ghulam Mohammad Commands where development of the irrigation systems is currently in hand, the emphasis will be on reviewing proposed canalisation extension plans and checking the operation of canals already in use.

From the results of these studies it will be possible to assess the general requirements for canal remodelling to achieve improved control and where applicable increased supplies.

Seepage losses from canals forms another important subject for study in the irrigation system. An attempt will be made, using actual observations to estimate the total losses between the head regulator and the farm in the three Barrage Commands. Since canal losses account for a very large proportion of all the water diverted at the head of an irrigation system, it is considered that this part of the overall water requirement merits careful study. The aim will be to take a sufficient number of observations to be able to make a reasonable assessment of the total losses in the different canal commands, taking into account major differences in rates of seepage along the canals.

The location of stretches of canal where seepage is heavy and where waterlogging is resulting is being done by aerial reconnaissance supplemented by inspection on the ground. Seepage estimation by heat flow analogy methods using observations taken during and after the closure period will be attempted on a number of main canals. These extensive studies will be carried out by observation of water-table levels on cross sections perpendicular to the canals. These observations are sued to derive the seepage rate by means of flow nets. Tank tests, which involve bunding off sections of channel and measuring the rate of loss, will also be performed on selected sections of smaller canals, and on water-courses. The results of these seepage studies will be made use of in estimating overall water requirements and in determining the economics of canal lining leading to general recommendations.

(*f*) **Drainage.**

The main objective here is to establish the most economical and effective means of drainage for construction in the different parts of the Region. Studies will cover the alternatives of tubewells and seepage drains, both open

and tiled, as well as surface drains required for disposal of surplus surface water, rainfall run-off and un-usable tubewell water.

Particular attention will be given to the economic analysis of the various alternatives for drain lines, out-falls and slopes and the feasibility of pumping in the line of the drain. Comprehensive coverage for the drainage of the whole Region will be provided, so as to form a framework within which the preparation of individual drainage construction projects can be brought forward.

Studies will include the possibilities of re-use of drainage water, as for instance from rice areas, when this is feasible.

(*g*) Consumptive use

In order to assess the water requirements of crops and to estimate overall water balance in the different parts of the Region it is necessary to have reliable figures for crop consumptive use. Examination of available theoretical methods for calculating consumptive use will lead to the selection of one which can be safely applied in the region. Consumptive use tables for the main crops and major vegetative types will then be prepared.

At the same time an attempt will be made to develop a method for direct measurement of consumptive use by studying and measuring moisture depletion in the soil. An attempt will also be made to measure in the field the actual consumptive use of major crops in different climatic zones and on different soil types.

The studies will include the estimation of evapotranspiration and evaporation from uncultivated and fallow land so as to obtain a more accurate assessment of the overall water balance.

(*h*) Surface storage

In Manchar and Kalri lakes the region possesses two surface storage sites which might well be worth developing or improving so as to provide for additional storage of the Indus flood flows for later use during the winter season. The location of any further potential storage sites is being investigated and observations designed to improve the accuracy of estimates of reservoir life are being made. In Kalri Lake, which is at present being used for seasonal storage of the Indus waters, sediment observations in the feeder canal and silt surveys in the lake are to be undertaken.

The economics of any such schemes will need careful study and must be evaluated for various possible operating regimes.

(*i*) Studies of hill torrents

To the north and west of the irrigated areas numerous hill torrents of varying sizes discharge their flood water into the plain. Most are dry for nine months of the year, but in the rainy season their flood flows often breach the protective bunds which have been constructed round the areas cultivated

by irrigation. Most of these torrents support small areas of 'sailaba' cultivation.

The object of these studies is to make a general appreciation of these torrents from the points of view of flood protection and of optimum use of the water for growing crops. Flood flow will be measured and sediment transport measurements will be taken where conditions permit. A quantitative estimate of erosion within the catchments will be made. From meteorological and hydrological data attempts will be made to correlate rainfall and run-off. Present land use by 'sailaba' irrigation will be assessed.

2. **Land**

Land is not a limiting factor in the agriculture of the Sind. There is too much of it for the water supplies which have been available in the past. Part of the land commanded by the canal systems of the Region has, in fact, either gone out of use or has never been cultivated: and it is very necessary to determine the present state of the soil, the extent and location of the currently used land and the effort and cost needed to bring into cultivation by reclamation the unused land for which water is available. These three aspects are dealt with the following paragraphs.

(*a*) **Soils**

A study of the soils of the region is of first importance in the development of any irrigated area. The general aim of determining the level of fertility of the soils applies mainly to those lying within and immediately below the root zone of the crops. Additional information at deeper levels may be required if deep open drains are required, so as to establish permeabilities for use in the selection of drain spacings and to sample the material in which the drain will be constructed. The soil survey is also an important source of information on the depths to water table and the salinity status of shallow ground water.

The information is obtained by putting down auger holes at regular intervals throughout the area and making field notes of the texture and structure at different levels. Permeability measurements are also made in the auger hole. Samples of the soil and of the ground water are taken and analysed in the laboratory. The analysis of the soils covers the salts present, exchangeable sodium, boron content, nutrient status, etc; the ground water analysis includes the concentration and identification of the salts present. Other necessary determinations are the soil-water relationships such as field moisture capacity, wilting point and infiltration rate.

Much of the area has already been covered at a density of sampling of approximately one auger hole to every square mile. The remaining area is being sampled at one hole to ten square miles in the first instance, to be followed up by closer spacing where this is indicated on analysis of the results or from land use and reclamation studies. Where the water table is high and a salinity problem already exists the intensity of sampling is increased to a

density of one hole to every two square miles.

The studies in abandoned land and the agricultural studies being undertaken in water-course commands involve special soil surveys at closer spacing which are being co-ordinated with each of these study groups. Co-ordination is also necessary with sections dealing with fertility problems, water table observations, salt and water balance studies and canal seepage studies.

(*b*) **Land use**

Broad land use surveys are being carried out throughout the area to determine the present location of cultivated and uncultivated lands, the latter being sub-divided into land which has never been cultivated and abandoned land. In addition more accurate classification and mapping is being undertaken in selected areas to give a detailed classification of the land use and the land form patterns. The results of these surveys are mapped in conjunction with the soil salinity and water table level.

(*c*) **Reclamation**

For the purpose of this study reclamation is defined as the process of removing excess soluble salts and/or excess adsorbed sodium from soils so that crops are able to thrive on them.

The work has already been started in the pilot reclamation project where an open drain system has been constructed and leaching trials instituted. These are being continued and extended to include field cylinder soil infiltration tests, the selection and establishment of salt resistant plants which might be of significance in reclamation, the effect of ridging crops to facilitate establishment in salty areas, the testing of the tolerance of selected crop varieties to salt and finally the study of the reaction of soils of varying pH and gypsum content, both morphologically and chemically, to systematic leaching by sweet and saline water. Additional trials have been started with special emphasis on the use of saline and fresh water for leaching.

At the same time additional surveys of saline areas will be undertaken to investigate the nature of the soils which are contaminated. A collection of surface and profile samples will be made and from laboratory examination and chemical analysis they will be classified. Representative soil classes will be subjected to leaching trials in the field; each leaching being followed by chemical analysis and the morphological examination of the profile.

This preliminary work will be followed by a full programme of reclamation trials with crops commencing in the winter period. Due emphasis will be placed on the economics of the reclamation processes adopted.

3. **Farming**

It seems likely that spectacular results in increasing productivity can be obtained by some relatively simple changes in farming methods and, therefore,

the farming studies may be the most important of the whole investigation. Such results can only be brought about by persuading the individual cultivators and land owners to adopt the changes and by supplying them with the means to do so.

They have been divided into four sections and the detailed investigations in each are set out in the paragraphs below :

(*a*) **Agricultural Surveys**

Before the future planning for increasing agricultural production can begin, it is essential to have a sound knowledge of existing agricultural practices and to appreciate fully the factors which at present limit production. The informations can only be obtained through direct enquiries by intelligent and highly trained field staff made in selected areas with as wide a regional cover as possible. The aim is to select and study 60 representative water-courses and special areas within the three barrage commands covering an acreage of from 25,000 to 30,000. For the whole period of the investigation each selected water-course is subjected to continuous study which will cover every aspect of farming, including animal and crop husbandry, water usage, credit, nutritional studies, marketing, etc.

The discharges at the water-course head will be recorded and in addition in twenty cases, where special farms are under examination, the water is to be metered.

(*b*) **Agronomy**

The main object of these studies is to increase the yield per acre through suitable combinations of improved farming methods. Special attention is being paid to the use of fertilisers, pest control, improved cultural methods, improved crop varieties and correct water use.

Initially a series of fertiliser trials have been laid down, mainly in the selected water course areas, with special emphasis on nitrogen and phosphate and their inter-action. Although local evidence suggests that the supply of potash in the alluvial soils under investigation is adequate, potash treatments nevertheless have been included in 14 exploratory cotton fetiliser trials scattered in water course areas throughout the region. The outcome will determine whether or not potash requires further investigation in the next season. Nitrogen and phosphate trials on wheat and other crops and perhaps in association with potash will be planned at the end of the rains for establishment in the following winter season.

As rice does not seem to respond to potash, it has been decided to omit it from rice trials and to examine the effect of different levels of application of nitrogen and phosphate. The rice trials will also be undertaken in selected water courses all over the region. By using the areas selected by the Agricultural Survey Section the results will add to the information becoming available

in those studies and also ensure a higher level of day to day supervision.

In most countries of the world with inadequate transport facilities and long distances between the places of production and use great importance is attached to urea as a source of nitrogen. A series of trials have been laid down to compare the responses of rice and cotton to urea and sulphate of ammonia. This line of investigation will continue in the winter season. As urea in certain countries has undesirable side effects which adversely affect crop growth, these trials will receive special attention.

It is also important to obtain information in the Region regarding the optimum time to apply nitrogen to rice, which may be influenced by variety, cultural practices, placement of fertiliser and climatic conditions. A preliminary trial has been laid down comparing seven application times against no nitrogen which should give certain information on nitrogen utilisation in the Region.

In all experiments outlined above the land preparation is carried out by the owner of the land and local practices will be followed, with the exception of ensuring pure seed for a reasonably uniform stand. More detailed studies of the effects of various cultural practices will also be undertaken. Where possible, these studies are combined with fertiliser and rotation experiments, variety trials, date of planting trials, etc.

(*c*) **Agricultural economy**

Here the task is to study factors affecting production, and once again the work is closely associated with the water course studies outlined under the sub-heading of Agricultural Surveys. The collection of data on economics of farm operations is being made from these selected units.

In addition these studies are being supplemented by obtaining information from co-operative landowners who are farming large areas. As they are generally the more progressive members of the farming community, the information, which is offered freely, is likely to be more accurate. Commodity surveys are also part of the programme; these surveys bring into focus limiting factors both on and off the farm which act as barriers to the expansion of production. A further study is being made on institutional barriers to increase production such as land tenure systems, availability of credit, level of taxation and marketing systems. The information accruing in this programme will be used in forecasting effective demands for the supply of agricultural produce, capital output ratios and benefit cost appraisal of projects. Feasibility studies under local conditions of price support, subsidy schemes, buffer stock formation, etc., will be carried out.

(*d*) **General agriculture**

The farming information obtained from studies under the Agricultural Surveys, though detailed, comes from samples which in total represent only

a small part of the Region. This information must be supported by observations from outside the sampling areas, before it can be applied on a regional basis. The services of an agriculturalist who has had experience in developing countries are thus required. He and his team will study the present movement of commodities from the farms to primary markets and thence to secondary markets, assessing the volume of movement, the means used for transport and the improvement necessary in communications to ensure that the projected increased production can be moved efficienly and quickly. The engineering side of this study must also be covered by the Irrigation & Drainage Section.

The agriculturalist will be expected to deal with problems of general application to the Region, such as animal mechanisation, in its role of improving cultural practices, eliminating bottle-necks in the farming calendar, for instance in the threshing of crops. He would also pay special attention to livestock husbandry, processing and marketing of livestock products. Primary processing of agricultural products will also be his responsibility including ginning, oil extraction and milling. Fisheries tend to have been neglected in the past and an up-to-date appraisal is considered necessary to establish its role in the future development. The Agricultural Section has the responsibility of establishing accurate agricultural calendar for the different ecological and agricultural zones in the region. This is of great importance if more accurate estimates are to be made of crop water requirements. Obviously a great deal more attention has to be paid to the possibilities of introducing co-operation into the farming community, especially as a means of improving the return to the farmer for his efforts. The agriculturalist will study the situation in so far as the Lower Indus Basin is concerned to see what recommendations can be made for the inculcation of the co-operative principle into the future extension services.

Finally he will prepare recommendations for the form of the future agricultural extension service in the Sind. He will do this within the context of existing services bearing in mind the special responsibilities for development of the Agricultural Development Corporation in the Gudu & Ghulam Muhammad barrages and the Department of Irrigation in the Sukkur barrage.

DEVELOPMENT PLAN

Towards the end of the programme period the final analysis of all the information obtained will be made, leading to the formulation of the overall plan for the development of the region.

One of the major factors in such a plan is the quantity of water which will be available in the future. This will be derived from the assessment of effective rainfall, tubewell supplies, surface storage and canal losses. It will also depend on the supplies passed down the river from upstream in the Punjab,

including the water made available from storage reservoirs such as Mangla. The extent of development is thus partly dependent on the Master Plan for the whole Indus basin, and co-ordination of the needs of the Sind and Punjab areas will be necessary. An appraisal of the return obtainable on the money spent and on the water diverted will give a guide as to which area should have priority for the limited resources, but political and social factors such as the existing population distribution and present water allocations must also be taken into account.

The division of the available water within the region should be based on the results of the studies on fertility of the soils, so that as far as possible only the good land, *i.e.*, land which is either affected by salinity and high water-tables or easily reclaimed, is scheduled for full development. The principle should also be adopted of developing first those areas which will show a quick return for the least initial cost. This means that projects which lead directly to increased supplies of water, such as tubewells in fresh ground-water areas and surface storage schemes for holding over the kharif flood water for use in rabi, should be the first to be constructed.

The choice of areas for full development will also be influenced by the existing situation of land use and canalisation layout. Since an established system of canals already exists in the region it will not be practicable or economic to attempt to superimpose an ideal layout by large scale remodelling. Instead any remodelling must be restricted to specific objects such as the provision of increased capacity or the elimination of particularly bad alignments. The study of the existing canalisation will give the necessary information for the preliminary assessment of the need for such works and their extent. Again information from the land use study will be made use of in deciding the location of development areas so as to cause the minimum disturbance to the present system. The data being obtained on reclamation will also be employed here so as to ensure that only those saline lands which are capable of economic reclamation are included.

The provision of drainage throughout the whole region will account for by far the largest part of the capital cost of construction works. It is, therefore, of first importance to select the most economical and effective systems. In rice growing areas the system of drainage will be different from that in perennial cultivation; in perennial areas the salinity of the deep ground-water may affect the choice between tubewells and open drains. The investigation work is designed to make it possible to recommend an appropriate form of drainage under these varying conditions with reasonable confidence.

Flood protection is another subject which is being covered in the investigation so that the danger of loss of crops by flooding from the hill torrents is reduced. Works recommended for this purpose may also lead to increase

a small part of the Region. This information must be supported by observations from outside the sampling areas, before it can be applied on a regional basis. The services of an agriculturalist who has had experience in developing countries are thus required. He and his team will study the present movement of commodities from the farms to primary markets and thence to secondary markets, assessing the volume of movement, the means used for transport and the improvement necessary in communications to ensure that the projected increased production can be moved efficienly and quickly. The engineering side of this study must also be covered by the Irrigation & Drainage Section.

The agriculturalist will be expected to deal with problems of general application to the Region, such as animal mechanisation, in its role of improving cultural practices, eliminating bottle-necks in the farming calendar, for instance in the threshing of crops. He would also pay special attention to livestock husbandry, processing and marketing of livestock products. Primary processing of agricultural products will also be his responsibility including ginning, oil extraction and milling. Fisheries tend to have been neglected in the past and an up-to-date appraisal is considered necessary to establish its role in the future development. The Agricultural Section has the responsibility of establishing accurate agricultural calendar for the different ecological and agricultural zones in the region. This is of great importance if more accurate estimates are to be made of crop water requirements. Obviously a great deal more attention has to be paid to the possibilities of introducing co-operation into the farming community, especially as a means of improving the return to the farmer for his efforts. The agriculturalist will study the situation in so far as the Lower Indus Basin is concerned to see what recommendations can be made for the inculcation of the co-operative principle into the future extension services.

Finally he will prepare recommendations for the form of the future agricultural extension service in the Sind. He will do this within the context of existing services bearing in mind the special responsibilities for development of the Agricultural Development Corporation in the Gudu & Ghulam Muhammad barrages and the Department of Irrigation in the Sukkur barrage.

DEVELOPMENT PLAN

Towards the end of the programme period the final analysis of all the information obtained will be made, leading to the formulation of the overall plan for the development of the region.

One of the major factors in such a plan is the quantity of water which will be available in the future. This will be derived from the assessment of effective rainfall, tubewell supplies, surface storage and canal losses. It will also depend on the supplies passed down the river from upstream in the Punjab,

including the water made available from storage reservoirs such as Mangla. The extent of development is thus partly dependent on the Master Plan for the whole Indus basin, and co-ordination of the needs of the Sind and Punjab areas will be necessary. An appraisal of the return obtainable on the money spent and on the water diverted will give a guide as to which area should have priority for the limited resources, but political and social factors such as the existing population distribution and present water allocations must also be taken into account.

The division of the available water within the region should be based on the results of the studies on fertility of the soils, so that as far as possible only the good land, *i.e.*, land which is either affected by salinity and high water-tables or easily reclaimed, is scheduled for full development. The principle should also be adopted of developing first those areas which will show a quick return for the least initial cost. This means that projects which lead directly to increased supplies of water, such as tubewells in fresh ground-water areas and surface storage schemes for holding over the kharif flood water for use in rabi, should be the first to be constructed.

The choice of areas for full development will also be influenced by the existing situation of land use and canalisation layout. Since an established system of canals already exists in the region it will not be practicable or economic to attempt to superimpose an ideal layout by large scale remodelling. Instead any remodelling must be restricted to specific objects such as the provision of increased capacity or the elimination of particularly bad alignments. The study of the existing canalisation will give the necessary information for the preliminary assessment of the need for such works and their extent. Again information from the land use study will be made use of in deciding the location of development areas so as to cause the minimum disturbance to the present system. The data being obtained on reclamation will also be employed here so as to ensure that only those saline lands which are capable of economic reclamation are included.

The provision of drainage throughout the whole region will account for by far the largest part of the capital cost of construction works. It is, therefore, of first importance to select the most economical and effective systems. In rice growing areas the system of drainage will be different from that in perennial cultivation; in perennial areas the salinity of the deep ground-water may affect the choice between tubewells and open drains. The investigation work is designed to make it possible to recommend an appropriate form of drainage under these varying conditions with reasonable confidence.

Flood protection is another subject which is being covered in the investigation so that the danger of loss of crops by flooding from the hill torrents is reduced. Works recommended for this purpose may also lead to increase

in water available for irrigation, or the extension of 'raitab' irrigation in the piedmont areas.

Between the bunds which contain the river Indus lies an extensive area of potentially good land which cannot be ignored in any development plan. High levels in the river last for a comparatively short time and some cultivation is practised at present on the land exposed after the flood water subsides. Recommendations for making full use of this area will be based on the information obtained from this part of the studies.

Little reliable information is available on the water needs of the different crops which can be grown in the Sind. The investigation of the consumptive use of crops aims at providing this information, which will be used in the determination of the total water requirements of recommended cropping patterns. These cropping patterns will be selected after examination of the needs of the region and the existing agricultural practices. The economics of farming operations and the information obtained on every aspect of farming will be taken into account. The development plan will not rely on rigid adherence to any of cropping patterns recommended since the demand for different crops and price levels will inevitably vary as time passes; the studies carried out will make it possible to compare the water needs of different systems of cropping so that the final estimate of water requirements will cover a reasonable variation in the crops grown.

At present there are numerous factors limiting the yields of crops. If the projects recommended for implementation are to be able to pay their way, it will be essential to obtain substantial increases in the output, in addition to reducing construction costs to a minimum. It is abundantly clear that this can be done; the agronomic investigations have been designed to give the necessary data for assessing the increases which can be achieved and for recommending the ways in which they can be brought about.

In order to assess the repayment capacity of the beneficiaries and to set out a preliminary plan for levying charges, the agricultural economic studies will include detailed farm budgets under existing and future conditions.

The studies in general agriculture, communications, marketing, education, etc., will enable recommendations to be made for a balanced programme of agricultural and industrial development for the whole region.

Finally it should be stressed that the overall plan for the former Sind Region is only of limited value unless it is integrated in a similar plan for the whole Indus basin.