Role of Research in the Control and Use of Water

By
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Applied Research can serve the national requirements only if it is geared to the development projects of the country ; for it can then solve immediate and important problems facing the nation. Different countries at various stages of development have different emphasis and priorities for the solution of their problems. A highly developed country trying to keep its supremacy as a world power may be given high priority to researches for developing supersonic planes, rockets, missiles and satellites orbiting the earth. Another country may give high priority to research problems for evolving more efficient machines than hitherto produced for competing in the world market. In a developing country like Pakistan the most basic problems facing the nation are :

(*i*) To feed its teeming millions by improving and extending agricultural industry by making best use of the water and land resources.

(*ii*) To develop more water and power resources and natural resources like gas, oil, atomic power, etc.

(*iii*) As the power becomes available, to develop industrial potential based on natural resources and raw materials.

Both for the Agricultural and Power development, the control and utilisation of water is the first important prerequisite. Even the industrial development can only follow a rapid growth of cheap power which primarily depends on harnessing all the water resources for power development. Obviously, therefore, the utilisation of water for irrigation to enhance agricultural production and its conservation and use for power production to achieve rapid industrialisation are the two major aspects of National Development. Research efforts in these fields will naturally be of direct and paramount importance to the country and therefore should receive high priority and allocations of funds, research facilities in men, materials and equipment.

The control and use of water resources includes Irrigation and Drainage, Power Production, Navigation, Flood Control, Watershed Management, Industrial and Domestic uses of water, Recreational and Wildlife uses (as fish hatcheries). In this domain pollution treatment and salinity control are

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important subjects for preventing water becoming harmful to human beings, animal life and crops respectively. Similarly sediment control is essential for prolonging the life of the water ways and reservoirs and in the interest of most efficient performance of hydraulic structures.

STATUS OF RESEARCH FOR CONTROL AND USE OF WATER

There is no research organisation in the country which can claim to have carried out research on all the above facets of control and use of water resources. The research fields which have received some attention are : Irrigation, Drainage, Flood Control, Hydel Power Production, Salinity and Sediment Control. This is due to the fact that applied research is generally undertaken to solve the problems of design, construction, operation and maintenance in a particular industry where they arise. Generally the awareness of these problems leads to applied research. In West Pakistan so far agriculture has been the major industry, and it can rightly be said that the history of development of this industry is the history of the development of water resources. In the last one hundred years an extensive irrigation system—one of the largest compact systems in the world—has been set up in the country. Naturally, there were large number of problems for solution. The necessity for research was realised by Irrigation engineers as early as 1916, and a small research centre was set up in 1924 which grew with the need into a premier Research Organisation.

SCOPE OF THE PAPER

In this paper it is proposed to deal with the role the research has so far played and the part it can play, in fulfilment of national objectives in the development and use of water, power and land resources. As mentioned earlier the part so far played relates mainly to the Irrigation Research, the part it can play for solving problems in other fields of control and use of water is bound to receive more attention as navigational, industrial and domestic uses of water increase. However, these aspects have to be kept in view for the future development and organisation of research pattern in the country.

It is also proposed to discuss the necessity of creating most suitable climate of research and the method of streamlining research organisation in the matter of research programmes, research budgets, research evaluation, research utilisation and research dissemination.

SCOPE OF IRRIGATION RESEARCH

Irrigation in its limited meaning is the science of application of water to soil for the purpose of supplying moisture for plant growth. However, before

water is applied to soil, it has to be forecast, its available qualities are to be estimated and often measured, the water has to be stored where possible by dams, led through natural waterways by adequate river training and control, diverted at diversion weirs, passed through canals, bifurcated at regulators in canals, distributories and minors, and measured at outlets before delivering it to the farmer's watercourse. In this process all losses have to be cut down, consumptive use of water for various plants has to be arranged, accumulation of harmful salts in water or soils have to be prevented and proportional distribution of water and silt has to be ensured all the way from the offtake of main canal to the water course. All these aspects of the problems fall within the purview of Irrigation Engineering as practised in this country and, therefore, the scope of this subject covers a wide range of scientific disciplines comprising : Hydrometreology, Hydrology, Fluid Mechanics, Hydraulics of Structures, Soil Mechanics and Materials, Geophysics and Geology, Drainage and Flood Control, Soil Physics, Soil and Water Chemistry, Agronomy and Plant Physiology, Mathematics, Statistics and Electronics for modern instrumentation.

Even disciplines like Agricultural Economics, Sociology and Business Administration cannot be completely neglected.

HISTORY OF DEVELOPMENT OF IRRIGATION RESEARCH IN THE COUNTRY

The Irrigation Research Institute has not grown in the mushroom fashion. It has slowly and steadily developed with dire necessity and growing realisation of the need for Research and has passed through its own vicissitudes in the four decades of its life.

In the period 1915—1919 there was a strong realisation of need for Research in irrigation problems. Eminent Engineers in the country convincingly put forth the idea of establishing a research organisation where patient investigators, original research workers and practical mathematicians may be collected to devote whole of their time for carrying out systematic and scientific study of the problem in the field of irrigation and irrigated agriculture. In 1924, with the appointment of Mr. B. H. Wilsdon (I.E.S.) as Scientific Research Officer, work was started in a wing of Panjab University Chemical Laboratories with a small team of Research Workers. By 1928, a Mathematical Officer, a Statistical Officer and two Assistant Research Officers were engaged on evaluation of extent, causes and remedial measures of waterlogging and salinity and other irrigation problems. As early as 1929 Mr. Herbert Culvert, who was member of Royal Commission on Agriculture in India realised the inadequacy of the research effort in the field of Irrigation and after consulting leading authorities, as Dr. Keew in U.K., pointed to the fact that Irrigation problems

are not Engineering problems alone. He strongly urged that for Irrigation problem there was a dire necessity of a strong collaboration in a single fully equipped institute having a group of Specialists each responsible for a particular branch of Research. In 1929 Mr. Crump prepared a scheme for developing the Research Laboratory into Irrigation Research Institute, but only during 1931-33 could Dr. Mackenzie Taylor organise Irrigation Research Institute into the following sections :

1. Land Reclamation Section.
2. Hydraulic Section.
3. Statistical Section.
4. Physical Chemistry and Chemical Section.
5. Physics Section.
6. Mathematical Section.

Each Section was under a qualified scientist generally a Ph.D. with long experience and a leader of thought in his field.

In 1935, Hydraulic Research Station was organised at Malikpur and attached to Hydraulic Section to undertake large-scale Hydraulic model testing programme.

In 1940 a small centre for soil stabilisation was opened under the Physical Chemist which later proved to be the forerunner of Road Research Centre in the country. In 1943 a soil survey and cement testing Section was added to the above list.

In 1945, the Land Reclamation Section of Irrigation Research Institute was made into a separate Directorate of Land Reclamation to fully take care of the scientific side of reclamation operation in the field. The basic research activities in the fields of waterlogging and salinity problems were still centred in the Chemical and Physical Chemistry Sections attached with the Irrigation Research Institute.

At the time of Independence in 1947, the Irrigation Research Institute received a set-back, the Hydraulic Research Station Malikpur was lost, separate Statistical Section was downgraded and Physical Chemistry and Soils Sections were transferred to Directorate of Land Reclamation. For the first time the group of Specialists in various allied basic fields were separated to work in different compartments. The basic research activities in the fields of salinity and waterlogging problems were mixed up with the control of land Reclamation operation in the field and the help and co-ordination of Mathematicians and Statisticians were, so to say, cut off from these important problems.

After Independence in spite of paucity of staff the Irrigation Research Institute and Land Reclamation Directorate carried on as best as they could with the amputated limbs. Hydraulic Research Station at Nandipur was

established in 1951 which has now grown into one of the best in the East. In 1954 a post of Research Officer, Hydrology and Groundwater was added with no supporting Research staff. A number of schemes for reorganisation of Irrigation Research Institute were prepared between 1949 to 1959 and submitted without any result. In spite of the fact that the Irrigation Research Institute after 1955 had to carry out work for the entire West Pakistan comprising old N.-W.F.P., Sind and Bahawalpur areas, the staff was the same as the amputated strength after independence. At this stage it was almost impossible to carry on the work with sanctioned staff. A large number of urgent problems were on the waiting list.

The reorganisation scheme submitted by the writer in 1960, met with some success ; the 1st phase being approved in 1962, for the II plan period and 2nd phase in 1966 for the third plan. The objectives of the reorganisation were :

(*i*) Creation of a unified Research Organisation capable of undertaking work in nearly all the subjects falling under the accepted scope of Irrigation Research.

(*ii*) The work of Irrigation Research is proposed to be split up into six Research Divisions or Directorates. Each Research Division is proposed to be under the charge of a Principal Research Officer or Director supposed to be a leader of Research with high qualification and long research experience. Each Research Division is further split up into Sections under a Senior Research Officer as group leader with work so distributed that most of the subjects enumerated in the scope of irrigation are covered.

The following are the proposed Research Divisions or Directorates, each under a Principal Research Officer/ or Director: For details see Organisational Chart (Fig. 1).

(1) Hydraulic Research Division.
(2) River Research Division.
(3) Hydrology & Drainage Division.
(4) Land Reclamation Division/Directorate.
(5) Soil Mechanics, Materials and Engineering Physics Division.
(6) Mathematical and Statistical Division.

The scope shall have to be further extended to include some of the subjects not yet receiving attention.

(*iii*) To establish co-ordination, avoid duplication and to make common facilities of Mathematics, Statistics, Laboratory Workshop, Instrumentation, Libraries and Publication facilities etc. available to all the divisions in one organisation without duplication.

(*iv*) To remove the defect and deficiency of too much work on too few shoulders as was the case after Independence, and specially after One Unit.

(*v*) To improve the status and emoluments of Research Staff to attract better qualified men for research.

(*vi*) To expand facilities of laboratory space, equipment and training of personnel and increase research potential for the solution of the basic and specific research problems in irrigation subjects.

ACHIEVEMENTS OF IRRIGATION RESEARCH

The Irrigation Research Institute attained some outstanding achievements through patient work of Scientists and the collaboration of Engineers in the field. It is not the purpose of this paper, nor possible in the short space available, to recount the achievements in any detail. Only some of the more important works which have either received wide recognition or become part of the Engineering practice in the country are briefly recounted without going into details :

(*i*) Hydraulic structure on sand foundation

Work done on design of weir on sand foundation by hydraulic models, electrical analogy, mathematical and statistical treatments and field observation and analysis produced methods of calculating uplift pressure and exit gradient and provided design criteria now widely accepted and used.

(*ii*) River Training and Control

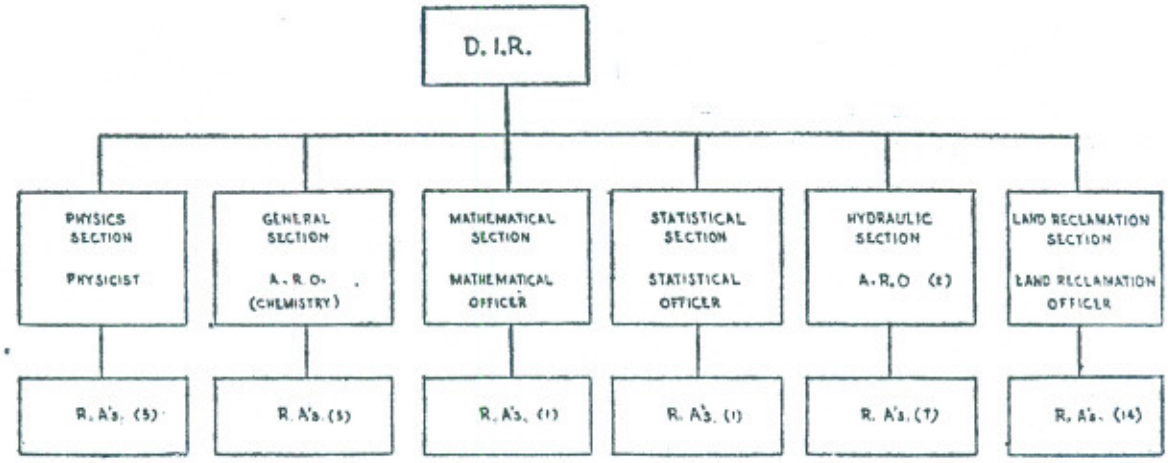
New concept and methods have been introduced by Irrigation Research Institute for river training and control by means of spurs and pitched stands. Extensive research on localised scour, shape, optimum distance and projection ratio of spurs for river training and bank protection have been carried out. The work has found references in well-known literature on the subject.

(*iii*) Design of Alluvial stable channels

The work on Lacey's regime theory was started in I.R.I. in 1930. The Institute within a very short period successfully introduced a number of formulae partially corroborating and partially improving Lacey's relationship. The recent research (1960-63) in the Institute have caused a further break through as new relationship has been developed to include the sediment charge as yet unaccounted for in the theory. This work has earned appreciation from all over.

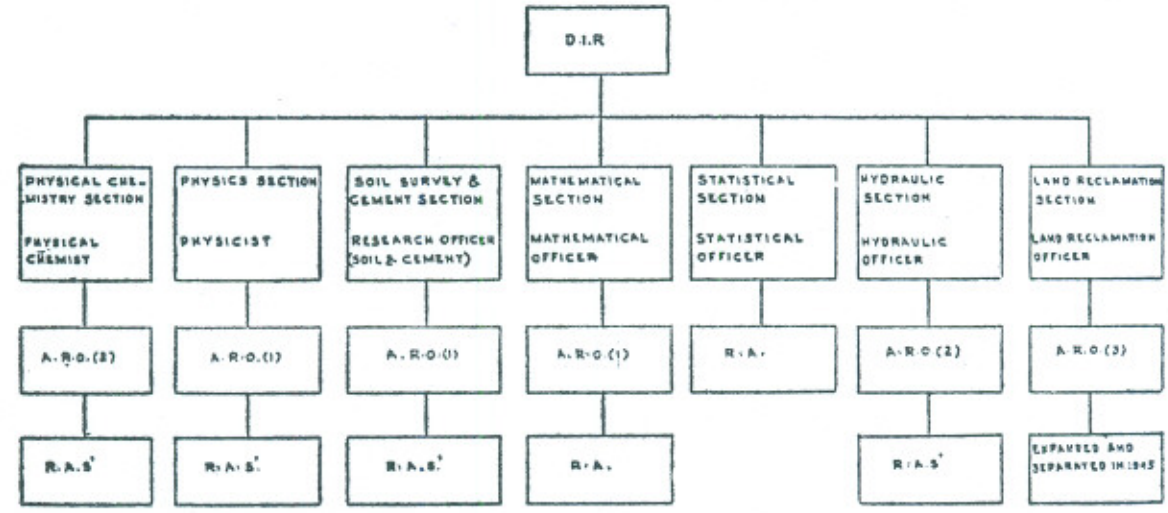
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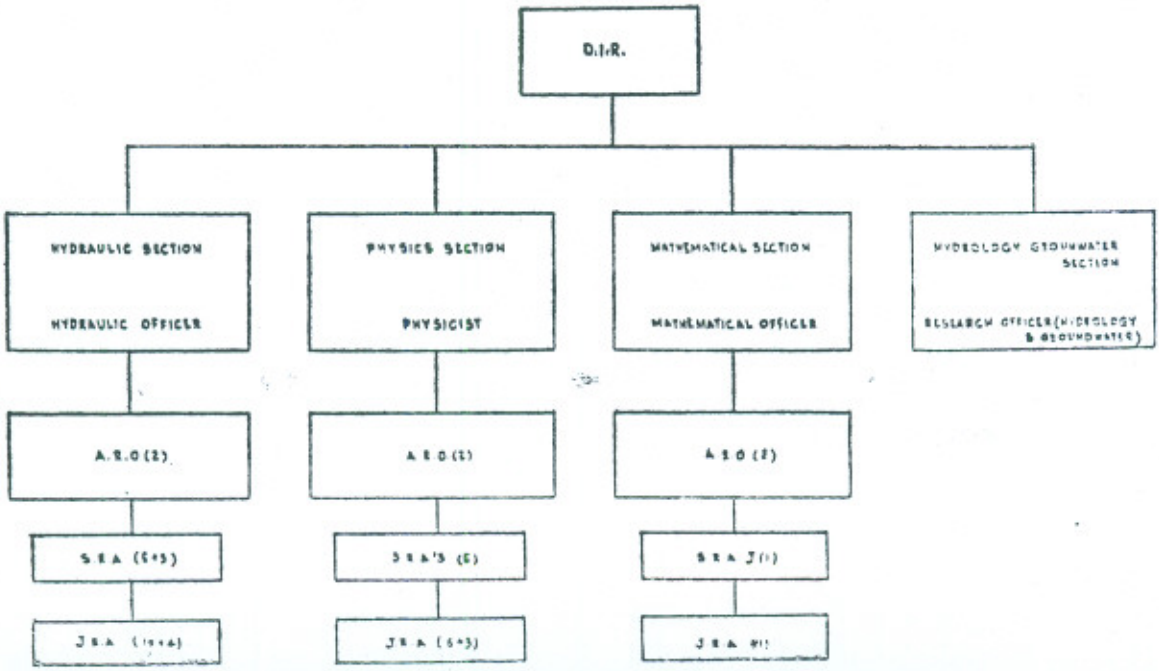
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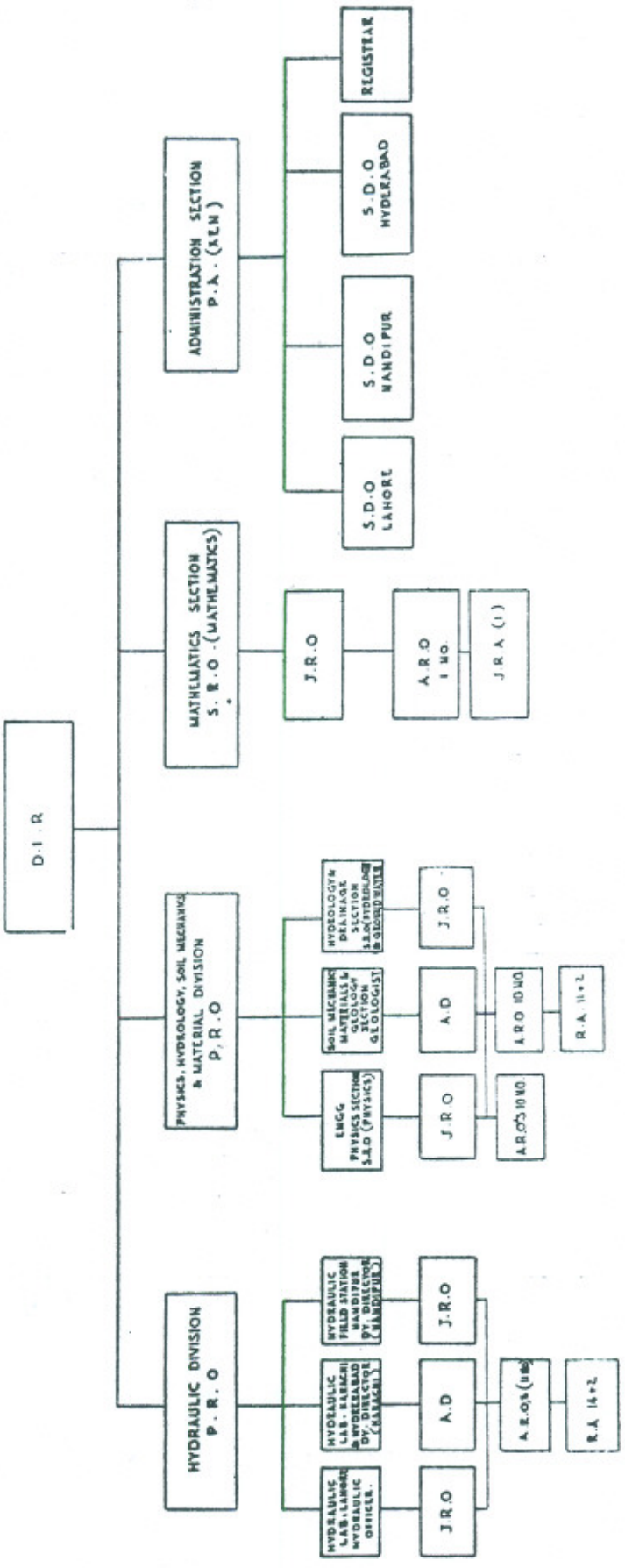


SANCTIONED GAZETTED STAFF IN I.R.I. LAHORE

DURING 1947 POST-INDEPENDENCE-1958



SANCTIONED GAZETTED STAFF IN I.R.I. LAHORE.
DURING 1960-65



(*iv*) Design of Weirs from Surface Flow Consideration

Researches carried out in this field have established guiding principles on location of the barrages in alluvial rivers with respect to the river axes and their khadirs. The Institute has proposed methods of estimating accretion and retrogression for fixing the crest and stilling basin levels of weir, to make the work safe for worst conditions of flow.

Energy dissipation devices for barrages are standardised and are now widely used in all hydraulic structures.

Experiments on location of headworks and protection of construction area during construction stage have invariably been conducted in Irrigation Research Institute for all headworks constructed from 1935 to date.

(*v*) Design of Silt Excluders and Ejectors

This is another field in which the Institute has contributed a lot. The design of different shapes and forms of silt excluding devices, fixing of the optimum working condition for discharge extraction, optimum pocket width and divide wall length in relation to offtake width have been determined. These are now in use as guiding rules in design.

(*vi*) Canal Falls and Syphons Spillways

The studies on the hydraulic behaviour of various types of canal-falls for fixing the optimum dimensions of various elements of design have been carried out in the Institute. These studies have introduced various new concepts and devices such as aero-baffles, hooks, spreading floor method of expansion, double drop falls etc. The study on the design of syphon spillways met with success and an efficient design of syphon for use at different hydel station was evolved.

(*vii*) Canal Outlets and Distribution of Water

An extensive study on the effectiveness of different types of outlets such as open flume outlets, A.P.M., rigid modules, etc., have been carried out and standardised to give measured water supply to zamindars.

(*viii*) Investigation on Sediment

Starting as early as 1933, the Laboratory attempted to evolve instruments for sampling of suspended sand and analysis of sediment characteristics. Numerous silt samplers for suspended and bed load were evolved. Some of the apparatuses for analysis like optical lever siltometer, Puri siltometer and air siltometer were concieved, designed and perfected in our own Laboratories.

(*ix*) Canal Lining

An extensive study on the best lining specification for canals has been in progress for a long time. As a result of these investigations some standard specifications for the best side slopes, optimum thickness of bitumenous layer, compaction methods and back drainage, have been evolved. Research on the Lining of Canal by using Sealant emulsions in flowing water is at present in progress.

(*x*) Waterlogging and Salinity Investigations

Investigations on this subject were started from the very inception of the Laboratory. The special problems dealt with were the classification of the soils, the development of field practices of reclamations, consumptive use of water for different crops. Important contribution on the various aspects of these problems are to the credit of this Laboratory.

(*xi*) Tubewell Investigation

An intensive programme of research was launched in Irrigation Research Institute for the investigation of different aspects of the tubewell problem. The performance of tubewells, their hydraulic characteristics, cause of the deterioration of strainers due to incrustation and corrosion, discharge and filter-length relationship, effects of shroudings on the yield of tubewells, designing of cheap and durable strainers in saline subsoil water-table were some of the important aspects of the study. A survey of the different types of tubewells in the province was conducted to assess the life and efficiency of each type. The idea of multiple strainer, to get increased yield from shallow depths, resulted from the experiments in this Laboratory. Interference of multiple strainer under various field conditions was another problem studied. The researches made in this connection have been of vital importance in designing and evaluating the tubewell projects for combating waterlogging and salinity problems.

(*xii*) Dewatering of Foundation

As a result of this study the old and costly conventional process of open sump pumping for dewatering of pits for constructing hydraulic structures has given place to shallow tubewell process. The number of tubewells and their location for dewatering a pit under a given condition of subsoil water table can be predicted from electric analogy studies.

The processes developed has been successfully used in the constructions of Ravi Syphon. Repairs to Panjnad Headworks, Chichoki Hydel, Guddu Barrage and many other projects.

(*xiii*) Electrical Analogy Techniques

In 1935 the Irrigation Research Institute developed the electrical analogy technique to study uplift pressure under weirs. During the last 29 years it has been used to study problems of subsoil flow, drainage, tubewells and their interference. The development of technique has successfully cut down the cost of projects and made the designs more sound.

(*xiv*) Electrical Resistivity Techniques

For modern design of heavy structures a thorough soil exploration is essential. With this technique it is possible to determine the location of rock in a river bed, position and depth of clay layer in an alluvial soil and the elevation of ground water and its nature etc., without actual boring. This technique has been used by this Laboratory as an ideal tool for in expensive and tolerably accurate exploration. The equipment developed and improvised in the laboratory has given fairly satisfactory results in the determination of over-burden at Mangla, Tarbela, Kot Kari and several other sites.

(*xv*) Gauge Discharge Data of Rivers

Gauge discharge data of rivers at various sites are analysed to study the long-term trends of accretion and retrogression of rivers. This is an important study to show the tendency of our rivers in silting or scouring in different reaches.

FUTURE PROBLEMS IN THE FIELD OF CONTROL AND USE OF WATER

There is a time in the development of an organisation when it has to take stock of previous achievements, difficulties and drawbacks, future plans and programmes. Such a symposium on research should provide an opportunity for an appraisal and some looking ahead. The questions that arise are :—

- What has been achieved so far ?
- What are the gaps in the existing status of knowledge and practice?
- In what direction should research efforts be diverted to improve the knowledge and practices?

The research results so far achieved, as briefly described previously, may be commendable but should not satisfy a progressive and dynamic Research Organisation and make it static ; for there is much more unknown than known. Just to form an idea of the gaps in our knowledge and practices

I pose the following questions for which admittedly I have no final answers to satisfy my scientific curiosity, let alone to satisfy a third person :—

(*i*) Have we got a programme of Research for augmenting precipitation and increasing supply of water from atmosphere ?

(*ii*) Have we enough information by snow surveys, enough automatic rain gauge stations to make precipitation analysis and establish reliable rainfall run off relation for our river catchments and for drainage basins in the plains ?

(*iii*) Do we know enough of the physical properties of ice, and ice forming processes to use ice as a Dam materials ?

(*iv*) Are our methods of water measurement not crude when compared to modern techniques of micro-measurements of electronic currents, cannot we yet measure seepage in a channel by measuring discharge at two places reasonable distance apart ; for the order of error in the measurement is generally more than the order of seepage ?

(*v*) Can we measure the rate and direction of subsoil flow accurately in our aquifer ?

(*vi*) Have we got a reliable means of cutting down evaporation loss under condition of wind and waves ?

(*vii*) Can we effectively cut off seepage from any Alluvial channel without closing it for a long time ?

(*viii*) Have we got reliable apparatus for *in situ* determination of seepage in a flowing channel ?

(*ix*) Can we measure scour depth under flood conditions near piers, dykes etc.? (The structure proximity affects the echo sounding method ?)

(*x*) Have we got an apparatus to detect the position and size of a cavity under a weir ?

(*xi*) Have we evolved an apparatus to measure the rate of bed load transport in an alluvial channel ?

(*xii*) Can we estimate retrogression or degradation from the various factors affecting it ?

(*xiii*) Does the damage to launching stone aprons of spurs, guide bank heads not suggest that our knowledge and practice needs further development ?

(*xiv*) Have we obtained sediment discharge equations for stable channels taking all characteristics of sediment charge (*e.g.*, ratio of fine to coarse).

(*xv*) Can we rationally fix optimum waterway in a silt laden stream

of variable hydrograph ? What is most suitable discharge, (keeping the duration in view) in relation to which the waterway should be fixed to minimise undesirable islands under a given approach ?

(*xvi*) Do we have a design of a navigable channel *vis-a-vis* the variables entering the problem ?

(*xvii*) Are we equipped to undertake analysis for scientific control, distribution and use of water in the Indus Basin comprising storage in reservoirs, use in power plants, routing the flow through channels, rivers and links, integrating its use with underground water, to arrange supplies at various points to meet the demands calculated on strict consumptive use ?

(*xviii*) What is the optimum groundwater level for various crops in different soils for good plant growth ?

(*xix*) For places where we cannot reduce salinity in the root zone, salt tolerant plants can be grown. Have we worked on the physiology of salt tolerance and do we understand clearly the reasons for difference in salt tolerance? Do we know which salt resistance plants can tolerate what range of concentration of salt at various stage of development ?

(*xx*) Have we any work on cheap methods of desalinisation of water ?

(*xxi*) Have we effective means of control and elimination of mass and weeds of different varieties usually met with in our country?

(*xxii*) Have we got a means of accurately estimating the storage capacity of an aquifer, field method for measuring moisture control, movement of water in unsaturated zone, etc.?

(*xxiii*) Have we accurately measured vertical permeability to distinguish from horizontal permeability and account for it in our flow problems ?

(*xxiv*) Have we instituted a scientific economic appraisal of Irrigation water, taken from surface flow, or underground reservoir by means of different types of irrigation ? What are relative costs of different types of drainage measures ?

The list of questions on specific problems on which our knowledge and practices are deficient is by no means complete and comprehensive. They can be added and multiplied. Each question has many facets and variables making the problems complicated and difficult.

In what direction should research efforts be directed to further improve the knowledge and practices can be seen from some of the problems enumerated above and some others that can be added to these. Clear visualisation of a

problem is a prerequisite for the realisation of the need for Research. Once it is there, the Research programmes have to be drawn, the priorities fixed, costs of research projects are to be worked out, the results have to be justified to be commensurate to the effort and then budget allocations have to be obtained. All this alone will not do. It is of utmost importance that the right type of Research leaders and research workers be selected for carrying out a particular research programme. The co-ordination of Research Workers and Field Engineers has often to be affected by arranging discussion of results to achieve the final solution. Finally dissemination of Research Results by improved documentation methods has to be arranged for communicating to the agencies interested in the results. All these are problems of Research Management and Organisation and are the responsibilities of a Research Director. Whether a research organisation is progressive and productive or otherwise depends on how efficiently all the above matters can be handled and pursued by a Research Director.

SOME ORGANISATIONAL ASPECTS OF APPLIED RESEARCH

Having spent more than three decades in Irrigation Research, I think, before closing the subject I may as well put forth a few suggestions in line with universally accepted principles of streamlining the organisational machinery of Research to make it smooth running and productive. The recommendations relate to :—

(*i*) The necessity of laying down Research policy and programmes.
(*ii*) Machinery for approval of programmes and evaluation of Research.
(*iii*) Procurement of Research Workers—training, recruitment and service conditions.
(*iv*) Research budgets and Research Engineering.
(*v*) Dissemination of Research information.
(*vi*) Utilisation of results of research.

(*i*) Research Policy and Research Programmes

For applied research to be undertaken efficiently and effectively, it must be based on well conceived programmes reflecting real needs of the country generally based on a research policy formulated after thorough survey by bodies like Research Councils or Research Boards or Organisations controlling Research.

(*ii*) Research Programmes and Research Evaluation

There should be a body for scrutinizing programmes of Research, fixing priorities sanctioning and providing funds for these programmes. This body

should keep a balance between the fundamental and applied Research. There should be evaluation of Research programmes at least once a year to strengthen, modify or curtail programmes and remove bottlenecks, if any. The evaluation of an applied/basic research projects should be a formal review of the present and expected results also entailing an economic analysis of the money spent and the expected future costs of research keeping in view the utilization of the research results.

(*iii*) Research Workers—training, employment and service conditions

It is very important to give full attention to the selection, training of research personnel and research leaders. To attract real good men for research there must be prospects for Research Worker. A Research Worker in a Laboratory doing first class work should not lack prospects compared to his administrative colleague. The prospects at present are very limited due to fixed cadres, all the more narrowed by specialisation. For research organization limited cadre strength should be made flexible. Workers producing high quality work should not be held up to frustrate and should be able to go to position equivalent to highest in administration.

Apart from pay prospects, for a Research worker, the more important is the prospects of his becoming more useful with time, in the matter of qualifications, accumulated experience and research contacts. For this there must be ample opportunities of training inside and outside the country, opportunities for Research Leaders to exchange with similar workers in leading institutions abroad and facilities to present and discuss papers in international forums. The facilities of higher training are for the present, completely inadequate. There are no post-graduates and research facilities leading to Doctor's degree, on most of the subjects in our Universities. Naturally, till we create these facilities we must make a phased programme of higher studies of at least five men in each branch of a subject.

(*iv*) Research Budgets and Research Financing

The Irrigation Research Institute has been engaged in Researches on specific problems of design, construction, maintenance and operation and also on some basic problems in different fields of irrigation.

The specific problems are generally referred to Irrigation Research Institute by the Irrigation Department, Wapda—I.B.P. and Development, Agricultural Development Corporation, Pakistan Western Railways, Directorate of Bridges and Foreign Consulting Firms. The procedure for financing specific Research and on problems referred to from the above agencies and departments is for the present as follows :

For each study when referred to Irrigation Research Institute, a cost estimate is framed and after approval of the amount from the sponsoring agency and getting the amount deposited, the work is taken up. Excepting for Irrigation Department which controls and maintains Irrigation Research Institute from its general budget, all agencies sponsoring specific research projects pay actual cost of research studies plus 27½% for the staff and facilities created by the Irrigation Department. The amount of 27½% is deposited to the Government account without any amount being directly available for the development of the laboratory facilities. The development of the Laboratories is considered to be the responsibility of the Government in the Irrigation Department as a normal function.

Recently another type of research contract was made by Irrigation Research Institute for Hydraulic model studies with Wapda (I.B.P.). This contract was made after the World Bank had made thorough appraisal of the facilities and satisfied itself that the work can be taken up in our Laboratories. According to this contract, for a fixed monthly sum of Rs. 1,43,000 inclusive of a foreign exchange component of about Rs. 21,000, it was agreed that model studies for all problems of Indus Basin Projects will be taken up at the Hydraulic Laboratories and Nandipur Hydraulic Research Station of the Irrigation Research Institute. The amount given under the contract provides for the additional staff needed, development and expansion of facilities at the laboratories and the field station. The foreign exchange was used for adding new electronic instruments and two expatriates. The staff was sanctioned and appointed directly by WAPDA to simplify recruitment procedures and placed at the disposal of the Director to work in the I.B.P. Unit in Irrigation Research Institute. This contract has contributed considerably to the expansion of laboratory and instrumentation facilities, while the Laboratories carried out all the work (more than 150 studies) at about one-fifth the cost of similar work done in any good foreign laboratory, thus resulting in huge savings of foreign exchange.

The greatest difficulty arises in the case of funds for basic research programmes. For these research projects it is generally hard to convince a lay man in the finance and perhaps correctly so, because generally one can not show easily some immediate direct savings accruing as a result of these researches. The long-term savings are there in the form of improved designs, elimination of chances of failure or decrease in the cost of maintenance of structure, but all these are indirect savings and do not directly appear as a specific figure in the ledgers of the finance. Moreover Research is one activity among many competing for a share of public money, and there is an element of uncertainty in the matter of time and money and then all researches do not

lead to positive results. A research director has to face these facts and formulate his problems in lay man's language with clear grasp of the objectives to stress the short and long term gains. The financier generally cannot see the scientific value but he can understand the gains that can accrue. That is perhaps the reason why research boards are in a better position to judge the basic research projects and allocate funds for basic research than financiers.

In the interest of keeping a fair balance between basic and applied research a more streamlined procedure of financing is necessary to increase basic research activities which at present is not more than five to ten per cent of the work at our Institute.

(*v*) Dissemination of Research results

One of the most important activities at any well organized research Institute is the documentation and dissemination of research results. There are two distinct activities under this head : One relates to the collection and transmission of latest information and contributions from all over the world on a particular subject of interest for the use of Scientists working in that field. This is a sort of 'library activity' and usually consists of traditional procedures of acquisition, cataloguing, bibliographic preparation, storage of research results in classified form, preparing selected abstracts and preparing documentation utilising the various modern methods of micro-filming or direct copying of articles and making these available to reserach workers for their references. In Irrigation Research Institute there is a small library of carefully selected good books and latest journals on most of the subjects falling under the scope of Irrigation. Recently a copying machine has been procured and is now in use for making direct copies of articles from journals. For preparing bibliographies and abstracts from journals, a system of enlisting the help of workers in different fields in Irrigation Research Institute has recently been utilised for preparation of these documents and distribution to all interested persons. The lonely soul of a librarian could never do all this work. The library needs further expansion in acquisition of books, journals, equipment for better documentation and staff. This has to be done in the II phase of reorganisation of Irrigation Research Institute.

The second important aspect is the dissemination of research results to the agencies sponsoring the research projects and other agencies interested in the results. The compilation of the scientific data in the form of reports becomes essential. This is not a form of library activity, but needs a well equipped and staffed Publication Section. These reports generally have large number of figures and photographs and have to be issued with speed and in a

presentable form. Recently with the help of I.B.P. funds self contained facility for printing reports in the Publication Section of Irrigation Research Institute has been made. The following research publications are issued from Irrigation Research Institute :

Publication	Frequency of Publication
(*i*) Monthly progress reports	Two per month ; one for I.B.P. and the other for the rest of work.
(*ii*) Annual reports.	One per year.
(*iii*) Technical reports.	On the average 3-4 per month.
(*iv*) Memoirs	As and when work requires.
(*v*) Research papers in journals (reprints).	As and when ready.
(*vi*) Bibliographies and abstracts.	After 6 months.
(*vii*) Brochures and Pamphlets.	Occasional.

The publication section is as for the present financed by I.B.P. funds but has to put on permanent basis in the II Phase of reorganisation.

(*vi*) Utilisation of Research Results

Applied Research has been defined by some as "technical undertakings aimed at solving problems of practical significance restricted in scope and extent by the degree of likelihood that it will lead to practical rewards." It includes the studies undertaken with a specific practical end in view and excludes fundamental research activities of investigators whose choice of problems and manner of attack is determined entirely by personal curiosity. Applied research generally includes those aspects of scientific work having direct relationship to the problems of design, maintenance or operation and may lead to changes in design specification improved operational or constructional practices.

The general idea that research leads to a point where it can be directly used by industry is erroneous. In fact there are three distinct stages before any new result can be practically used. There are :—

(*i*) Basic and applied research.
(*ii*) Design, and
(*iii*) Development.

The terms 'basic' and 'applied research' have been explained above. In fact applied research is based on information derived from basic and fundamental research and the latter, therefore, must be given due importance ; for, a research on a basic issue, say mechanics of localised scour at an obstruction can save many specific experiments of applied nature, say, for choice and

design of training works or piers for a particular condition. In fact in research we sometimes reach a point when further practical applications must wait on the solution of a number of basic problems. That is why for a healthy growth of Research, a balance between Fundamental and Applied Research must be maintained.

The next stage following Fundamental and Applied Research in the evolution of a new thing, ideas or a practice is the 'Design'. This is essentially an engineering process and has to do with drawings tolerances, mechanics, strength of materials and may include manufacturing or construction methods, economic choice of materials and other practical matters. Leslie Simons[1] on analysing the conduct of German Research after World War II points out that "Research Workers are likely to be poor designers ; and besides that it is a disastrous prostitution of research talent to divert it to design work." The design should be mainly entrusted to design engineer trained and disciplined in applying scientific principles within established rules of safety with due regard to economy and national welfare. They cannot afford to make mistakes and hence generally apply safety factors in the design. In fact a serious mistake by a Engineer can damage his professional standing badly, whereas the Research Engineer's "most common activity is to make mistakes, recognise them and correct them.[2]" His training prepares him to become an expert in experimenting. Obviously Research and Design are distinct and separate stages requiring just the opposite types of training and approach to problems. The two should co-ordinate but never should the role of a research worker and a designer be combined in one. One has to decide to be one or the other.

A good Design Organization is surely as essential as a first rate Research Institute. It is in fact a necessary step for the utilisation of the research results and accumulated knowledge in the manufacture, production or construction of Engineering materials, products and projects. It is strongly recommended that design organisations of all the bodies utilizing research should be strengthened, otherwise Irrigation Research Institute will progressively be serving more and more the designers of the Consultants, choking the channels of knowledge to Design Organisations in the country which are shrinking in strength and importance.

The third distinct step in the utilisation of research results is the 'Development'. It is again an engineering process but slightly different from

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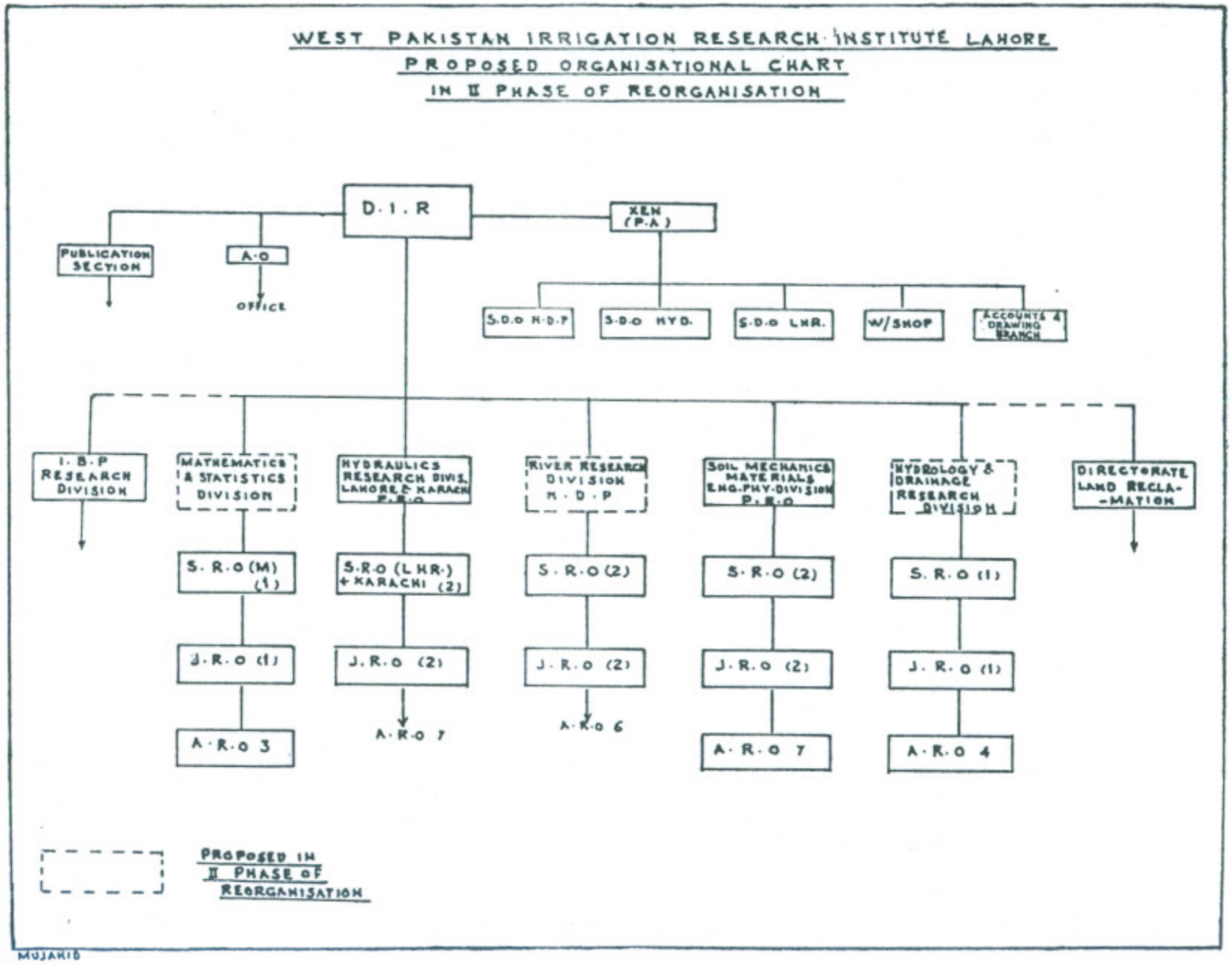
1. German Research in World War II. Leslie, E. Simon. An analysis of th conduct of Research.

2. What is Scientific Education (Dr. Edward Teller) quoted from Tram A. Soc. C. I. Vol. 128, 1963, Part V, p. 32.

that of a design engineer. It is the enhancement of the process of a design by the addition of practicality. It consists of thorough testing of the design, by subjecting it to proof procedures, the discovery of omission and deficiencies and their corrections. In fact it is a follow up of research and design, and requires testing under worst field condition. This should comprise a field unit collecting information on the behaviour of structures constructed in designs based on results of research and existing knowledge with an idea of removing defects and deficiencies. Again quoting Leslie Simon[3] "without development basic and technical (but not pure) research is sterile ; it lacks the stimulus of seeing its product come to fruition." In like manner, without research there can be no development."

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3. Loc. cit.


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W/SHOP
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A.R.O 7
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