ften der Deutschen Stiftung für Entwicklungsländer

Band 2

Water Development in Less Developed Areas

Transactions of an International Conference held in Berlin from 17 to 21 May 1963

With an Analysis by

H. P. Michael

DUNCKER & HUMBLOT / BERLIN

96,=

Water Development in Less Developed Areas

Schriften der Deutschen Stiftung für Entwicklungsländer

Band 2

Water Development in Less Developed Areas

Transactions of an International Conference held in Berlin from 17 to 21 May 1963

With an Analysis by

H. P. Michael

DUNCKER & HUMBLOT / BERLIN

DOK 169 A

IT 10/63

Gedruckt 1965 bei Albert Sayffaerth, Berlin 61
Printed in Germany

Table of Contents

A. Preface

Hardly another tool of economic progress appeals so deeply to the imagination, to the hopes and to the political consciousness of the emerging nations as water development. This volume gives the substance of a Conference which the German Foundation for Developing Countries has called from May 17th to 21st, 1963, to evaluate the economic, social, administrative, and technical lessons of far flung water management activities in recent years. The worldwide scope of the problems under consideration and the existing variety of opinions made the holding of an international conference appear to be the best of all available methods to obtain without delay universal and far-reaching answers.

The Foundation was fortunate in having the cooperation of some of the world's leading experts who by virtue of their activities as advisers to the United Nations and to national governments or as first water development executives to the nations of Southern Asia and other countries with underdeveloped areas were able to make distinguished contributions to the Conference. More subjects might have been treated, yet five days represented the most generous sacrifice of time which could be asked for; so the agenda was already overloaded.

The size of the papers presented has been shortened to meet the requirements of publication; an exception was made in respect of such central subjects for the discussion of which the Conference had been originally planned

Acknowledgements are due to Professor *H. Press*, President of the Berlin Water Congress and Exhibition, 1963, for the patronage given to the Conference. Special appreciation goes to Mr. *H. P. Michael*, Head of the Hydrology and Water Development Section, Federal Ministry of Transport, who suggested the holding of the Conference, directed it and analysed its results. I wish to express my gratitude to the authors of papers and recommendations for their outstanding work and to all participants for their active help.

Dr. *Gerhard Fritz*
Director-General,
German Foundation for Developing Countries

B. Water Development in Less Developed Areas

An analysis by H. P. Michael

I. Introduction

Political pressure for a rapidly accelerated pace in development as well as worldwide recognition of water resources management as one of the shortcuts to economic and social advance of the less developed areas have helped to sharpen the technical and administrative tools of water development work in recent years. The United Nations in particular with their special agencies and other international organizations with territorial or technical responsibility have taken initiatives for the improvement of techniques and procedures which lend themselves to application in the tropics and subtropics.

Such activity is gauged to take the angle of the developing countries. The governments of economically more advanced nations certainly benefit by it in respect of their foreign aid schemes, yet comprehensive answers to their principal problems in this sphere are still missing, and in spite of this worldwide effort that has achieved so much in a short period of time the difference in outlook on major water development schemes remains disturbing: on the one hand enthusiasm and complete faith is shown by the sponsoring nations, whereas a deep-seated reluctance of the taxpayer in Western Europe vis-à-vis such projects is not easy to overcome. He knows that from the economic, social, technical, and administrative angle the majority of water projects offers a complexity of problems and dependence on regional knowledge almost unknown in connection with other efforts in the public works sphere; and as it is his prerogative to have all expenditure from public funds critically examined by his representatives, he insists on conclusive evidence that for foreign aid adequate standards of social and economic efficiency, of technical planning and execution and of administrative care are applied.

A review of the state of our knowledge in this sphere of activity must soon arrive at gaps and deficiencies which in numerous instances are responsible for sharp disappointment at the relatively poor contribution made to the national economic advancement by otherwise immensely popular projects; irrespective of capital assistance being received or the cost of the whole scheme being financed from revenue, low income nations cannot afford to indulge in some of the rather lavish expenditures which their richer fellowmen occasionally favour. If water development — this potentially very dynamic tool of economic and social progress — goes on to have a conspicuous share in the national investment programmes, an analysis of the world-wide experience of such schemes is needed to enforce better efficiency for the future. Such evaluation will have to concern itself with the social and economic part which water projects can play in the framework of a development programme and, consequently, with the choice of schemes; it will have to analyse technical and administrative policies to be followed if the objective of such undertakings is to be reached and, finally, will have to deal with technical methods and procedure.

An activity, in which so many men of eminence in many lands have excelled for many years, has brought forth experiences which yield useful and immediate answers at a time when research will have to go on for an indefinite period before its results can be effectively evaluated. This consideration, and awareness of a clear need have induced the German Foundation for Developing Countries to ask the following questions:

1. Is it possible in the absence of economic and social surveys on the impact of water projects to develop a sufficiently reliable technique of decision making which will enable the government agencies concerned, both in the country sponsoring a scheme and in the country giving financial aid, to be aware of the full implication of the work they are undertaking?

2. Is it possible to sum up the manifold technical and administrative experiences gained from water management in developing countries as background knowledge for a foreign aid policy in this sector? Can general principles and technical methods be derived from the investigation and execution of water projects in developing countries, and can general rules for the administration of water be suggested?

It is justifiable to explain these questions in some detail.

II. The Background of the Conference

Water development stands for a multitude of technical measures designed to influence the hydrologic cycle for the purpose of either creating benefits or forestalling danger to life and property:

By irrigating or draining land, agricultural production for food and cash crops is raised to a much higher level; by generating hydro-electric power important assistance to industrialization is given; by providing community water supplies a major contribution to the health of populations, their self-respect and their amenities is made and one of the basic conditions for starting industrial production is fulfilled; by carrying out river training works effective arteries of cheap transport are opened to otherwise inaccessible areas; the ill-effects of floods are counteracted by the construction of large storage spaces and of levees; the pollution of potential sources of water supply is checked by creating systems of sewers and constructing sewage disposal works and treatment plants for industrial waste water. Several of these project types need for their implementation the construction of storage dams or weirs, whereas others with an equally strong social and economic impact on an underdeveloped area may imply a lesser degree of specialized technological effort, viz. the distribution of water points over marginal pastures to counteract overgrazing and soil erosion, the building of small reservoirs for fishfarming to alleviate famine of proteins, the construction of simple underground dams in sand rivers to hold back the moisture stored in river beds; the setting-up — to mention one of the less obvious uses of water — of a sufficiently wide water barrier to stop the advance of the tse-tse fly.

The concept of marshalling all water resources to obtain for the greatest number a maximum of benefits has been adopted by governments and experts of all nations. All new schemes must be in harmony with established or planned uses of water in the same catchment and no water management programme should go forward without exhausting all economic possibilities which multi-purpose and integrated river basin development can contribute[1].

---

[1] See Integrated River Basin Development, United Nations publication No. 58. II. B 3.

The term "developing" or "economically less developed" is applied equally to nations of ancient engineering traditions which in certain fields of water management have been among the world's most progressive and to others whose governments have only in the recent past discovered the benefits which such projects can bestow. Common to these non-industrial and low-income countries accessible to the free world are a number of circumstances deeply affecting the fate of schemes: the extreme physical conditions of the tropics or subtropics; lack of most data needed for the preparation of projects; shortage of technical staff at all levels; lack of essential facilities of the infrastructure. The political, social and economic realities of a developing country put the sense of responsibility of those concerned with the decisive stages of a scheme to the severest of tests.

Certainly the former colonial services have held and passed on considerable knowledge of water management under such conditions. Far from the centres of research and technological progress they have in many cases developed techniques especially adapted to the traditional skills of artisans they found and encouraged. Recent advances of technical science have replaced many of the old methods, techniques and procedures whereas others still live on. It is to be regretted that no competent book summing up experience of water policy, water development and hydraulic engineering in the former colonies has as yet been written.

One of the principal needs of the aid giving countries in connection with foreign projects is the agreement on acceptable selection criteria. It must be the obvious purpose of any careful investment policy to bring the major schemes to be financed into full coincidence with the central objectives of national development. As a rule such aims are expressed by the governments of the lower income countries in simple terms of economic and social progress. It is almost a truism to state that the connection between most technical schemes and the general political aim of an investment plan remains entirely unconvincing. The standardized criteria dealing with the financial and economic merits of projects do not admit conclusions how investments in the field of water development change the level and distribution of incomes and to what extent they succeed in getting a large section of the population closer to the fulfilment of their personal aspirations. In order to improve the technique of assessing projects, the lessons from detailed surveys in retrospect ought to be learnt: of surveys which show the full economic and social effects which water projects have had on their environment. However, hardly any project in the less developed areas has been evaluated, and even for the industrial countries with a long tradition of public works schemes such studies are missing. It may take a long time before such surveys are at hand; in the meantime it is highly desirable to devise a scheme of analysis which would make the reviewer at least aware of the intentions built into the draft project and check up on its contribution to the economic progress of the country.

It is essential to see the achievement of this symposium in a context with other conferences and international efforts: the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas; several ECAFE, FAO, WMO and WHO seminars; meetings of the International Section of Scientific Hydrology and others. Where it was possible to fall back on up-to-date papers and reports, themes were treated by giving references only. Some contributions could be kept brief for the same reason. Yet the principal subjects were covered by papers which were presented and discussed. The essence of papers, discussions and recommendations as well as certain characteristics were incorporated in the analytical part of this report. Some papers contributed to the symposium have a policy section and a section dealing with technical considerations and solutions under the difficult aspects of the less developed areas; certain papers cope with selected delicate problems, others give an almost complete guide to planning and design within the scope of the subject treated. Numerous references of a general or regional nature are added.

In a way this is the first attempt of its kind; it does not give the rudiments of a text book, but it may inspire more detailed work on numerous constituent subjects within the next few years.

III. Criteria for Decision Making

One of the achievements of the symposium was clearly the vivid interchange of views on a technique of decision making at the beginning and the end of the conference. The themes of *Gilbert F. White's* paper which is printed in full in the appendix of this report pervaded the whole conference and were repeated in several of the technical papers. A recommendation on "criteria for a review of water programmes" received the backing of the meeting. The ideas contributed under this heading appear to affect all development policy far beyond the limited scope of water schemes and are given here in some detail as they present an additional justification of the conclusions reached.

It was stated that without adequate analytical studies showing how a complex of changes in physical phenomena is to affect changes in the social complex, the reciprocal relation of several interworking systems cannot be forecast according to cogent rules. Hydrology and engineering give precise answers with regard to quantity and quality of the water to be supplied, to the size of floods to be safely disposed of, to the permissible draft of ships, to the output of a hydro-electric scheme. The background of social and economic development, however, to which a precise engineering scheme belongs, is in itself amorphous and vague.

Based on certain assumptions two systems of criteria — financial and economic — have been adopted for the analysis of public works schemes by the international organizations, commercial institutes and foreign aid agencies of national governments. "Economic justification" of projects according to this scheme of thought depends entirely on the quality of the assumptions which the analyst has chosen and on the weight assigned to benefits and costs. The following schedule compares the financial and economic criteria with yet another system which is derived from purely "political" aims and, in fact, most of the final decisions of governments in connection with water development take account of this type as well as of financial and economic types of analysis. As a rule the political assumptions are not clearly stated: they are implicit in the supporting analysis of the scheme and it is left to the reviewer to guess them.

Financial criteria, such as those used by the International Bank for Reconstruction and Development and by commercial bankers look

Methods of Analysis for Water Development Projects

		Type of Analysis		
		financial	*economic*	*political or other*
Assumptions	*aim*	reimbursability bankability	economic efficiency of the production plan	avoidance of political trouble, social reform etc.
	benefits b	vendible or reimbursable benefits	vendible and non-vendible, tangible and intangible	varied
	costs c	direct costs of construction and of operation	direct costs indirect costs	varied
	interest rate i	current rate	opportunity costs	opportunity costs
	time period t	5 to 40 yrs	40 to 100 yrs	1 to 100 yrs
	design criteria	$\frac{B}{C}$ max!	varied optimization or maximization criteria	varied optimization or maximization criteria
	standards	Int. Bank for Reconstruction and Development	UN, ECAFE USA, FAO	no set of standards

upon the investment aim in terms of bankability and reimbursement. Only vendible or reimbursable benefits count; as costs only direct costs of construction and of operating the scheme are entered. It is frequent practice to compute benefits and costs by taking their present value, thinking of a continued stream of benefits for the future. The interest rate for a given time period is the current rate. The principal design criterion of the scheme is maximization of the benefit-cost ratio. Obviously the procedure may lead to unexpected results because it tends to ignore or minimize facts which have a direct bearing on cash income and repayment. Frequently the indirect social costs of a project are minimized and disappointment follows after the scheme is underway.

Where for national planning a broader view must be taken, *economic* criteria ought to be applied. Publications by the United Nations, the FAO and ECAFE call for a wider assessment of indirect and intangible benefits and costs from water development schemes. Reimbursability may be included in the aims, but the accent will be on maximizing the economic efficiency of the production plan. Benefit-cost analyses, when carried out with care and comprehension, can suggest the broad effects of water development upon future streams of benefits and costs. They can take account of and seek to assign some value to all changes in productivity, whether or not the value can be taxed or recovered. They thus take into account numerous effects as indirect benefits and costs which would not figure in a financial analysis, viz. stabilizing village life, inspiring a population with a standard of human dignity, forestalling dislocation of economic life by floods, bringing bilharzia through irrigation water to the community, starting channel degradation or soil erosion, destroying scenic values. Some of these impacts may be extremely difficult to assess, yet they can be noted and their importance can be described. In the *economic* analysis the rate of interest is the opportunity cost: the price the national economy pays for not having invested in other productive purposes with a better return. Design criteria vary; the normal criterion is optimization: maximizing production, minimizing the strain on the economy, viz. minimizing cost of construction and/or operation of the scheme, minimizing the cost of floods or droughts etc. Many of the economically feasible projects are not financially attractive in terms of repayment.

The *political* analysis, if it deserves this term, reflects still broader aims, viz. social reform, deflecting general discontent, winning votes, creating symbols for the national economic effort. The approach to benefits and costs may differ widely from other analyses, yet as interest a lower rate than the opportunity cost would be an illusion. The *political or other* aims are frequently decisive and provide the key to the understanding of a project. To be able to guess such aims the analyst needs frequently the support of local inside knowledge.

The *financial* and *economic* systems of criteria are conclusive in themselves but treat each project in isolation instead of connecting it with broader national aims; a procedure for decision making, based on these standards alone, leads frequently to unsatisfactory results. This state is all the more deplorable as communities of low income with severely restricted possibilities of investing can least afford the luxury of spending funds on projects of relatively small economic and social efficiency. Without analytical surveys on the economic and social impact of water development projects, however, it appears premature to suggest new criteria; yet in the meantime a scheme of procedure must be devised which makes the reviewer aware of the implications of a project in relation to a policy programme. At *Gilbert F. White*'s suggestion the conference recommended that until such time as the results of surveys on the economic and social effects of water development become available for interpretation and thus more efficient tools for evaluating the prospects of a scheme become available all project proposals be accompanied by a rough *economic* analysis on lines indicated on the above schedule. This decision was taken in spite of the obvious limitations of the method, yet in order to link water projects with the aims of a national development plan, answers to the following six questions concerning each project proposal should also be asked:

1. Are the aims and designs criteria stated explicitly? It is essential to be aware of the real criteria built into projects and of the underlying mechanism of reasoning. Most decisions on water development are essentially political, at least nontechnical. Frequently irrational motives are the main spring of action (urgency to get major works under way, enthusiastic commitment which grows up around a particular project, etc.).

2. Does it canvass other means than water development to reach these goals?

3. Does it consider alternatives to the conventional engineering measures?

   Questions 2. and 3. belong together. In developing countries conventional engineering solutions frequently dominate public thinking; the technicians responsible for water development plans are charged with that task and have frequently but little occasion to design cheaper, more effective alternatives outside the province of water management.

4. Are the necessary complementary measures included?

   Unless a whole set of complementary measures is planned and carried out in detail, no perceptible impact on the economy is achieved. Unfortunately many schemes have been left without all or some of the complementary technical and administrative measures and are therefore ineffective.

5. Are fiscal limits recognized?

6. Does the project specify needed institutional changes?

   Most investments for water development remain relatively inefficient without a competent water department, a modern water code and progressive land legislation.

A discussion on economic and social methods of analysis brought forth objections from representatives of the developing countries who insisted that profound answers could not be supplied in all cases. If capital assistance were to be made dependent on the result of such detailed enquiry into the background of schemes, very little water development would be started during the next few years; it was argued that governments with a living tradition of public works administration and excellent experts of their own should not be subjected to the need of answering this questionnaire. The difficulties to be overcome in putting a scheme into practice were indeed enormous and nothing should be done to complicate further the delicate procedure of negotiating agreements on capital assistance. In defence of the above proposals participants from Western Europe explained the viewpoint of their representatives of public opinion who were conscious of the overwhelming need in the world and at the same time of the miserable insufficiency of available funds; hence their instruction that money should be invested in economically and socially most effective schemes only. It was admitted that precise answers could not be expected in all cases. An answer or its absence would in itself not disqualify a project, but the reviewer was entitled to know whether certain aspects had been investigated; he was entitled to analyse the connection between a technical scheme and the overall picture of national development.

Finally the meeting agreed on *Gilbert F. White's* above-mentioned recommendations regarding "criteria for a review of water programmes" in which it was stipulated that in addition to the results of financial and economic analyses the manifold general and technical lessons of water development activities of recent years should be carefully considered in order to avert difficulties and seize opportunities "for the benefit of all concerned". Such experiences gained in many countries are dealt with in the following chapters.

IV. General Problems and Conclusions

To reproduce some of the wealth of experience and detail brought forth by the conference it is advisable to split the second part of the report into a general and a technical section. This non-technical chapter is to deal with policy matters as water laws, organization of a department, training of staff, and with general aspects of water utilization projects: such as irrigation and drainage, community water supply and sewerage.

Institutional Difficulties

Institutional shortcomings were found to be the major handicap to promotion, successful planning and efficient operation of all water development projects; in most cases failure is due to the non-existence of proper water development authorities, to conflicts between multiple agencies having divided authority and working under conflicting policies, and to the absence of up-to-date water legislation.

The lack of hydrological data, the collection of which is one of the foremost tasks of a water department, disqualifies or postpones many urgent and promising hydro-electric, irrigation and water supply schemes in Africa. The progress of vital flood control projects in densely populated East Pakistan is severely hampered by the fact that an organization systematically gathering hydrological information is of relatively recent date only and the omissions of the past cannot be made up in a few years. *A. de Vajda* has described the ineffectiveness of numerous projects, due basically to the non-existence, incompetence or uncooperativeness of responsible organizations: many thousands of hectares of highly productive land under irrigation in Asia go out of production and turn permanently sterile every year as the danger of salinity and alkalinity has been disregarded, the systems of irrigation have not been adapted to the special needs of soil and climate and no proper drainage has been provided; bad land levelling, unsatisfactory distribution practices and a superstition among farmers that the quality of a crop depends on a maximum of water supplied, waste much precious water. In many developing countries water is not brought directly to the farmer, only the major canals forming part of the engineering project. The field systems are left to the rural population to complete which, however, is not always technically competent. Where drainage is provided, only the main drainage collectors are built without taking responsibility for field drainage. In one case 100 storage reservoirs were constructed by a country's irrigation department whose task ended at the reservoir. The distribution of water was the responsibility of another department which did neither possess the necessary technical staff to design the canal and drainage system nor was it able to assist the farming community in utilizing the water. No cooperation between departments was attempted and so the economic effects of a large investment remained negligible. In another country several storage dams with a capacity of 3,000,000,000 cubicmetres were constructed by an agency specially set up to provide water in a large arid area, yet no organization was created to utilize the water. Since then reservoirs are filling and evaporating every year without any utilization of the impounded water.

Equally during the symposium examples were given of outdated water laws neutralizing economic and social benefits of projects. In fact, at all stages of development existing tribal rights, ancient privileges favouring individuals or groups of people and the application of traditional doctrines — viz. the riparian principle for surface waters and the rule of unlimited use for groundwater — are absolutely incompatible with water development activities on a national scale. Industrialization and power development in economically ambitious countries were held up for years due to the difficulty of obtaining water rights or permits for such uses.

Institutional Needs

Upon discussing H. P. Michael's paper on *"general principles* of water legislation at different stages of development" the symposium considered the establishment of the following three institutions a prerequisite of successful water development:

1. *A strong water department or statutory body* which in the field of water affairs carries out the social and economic policy of the government. This organization establishes and maintains an inventory of all water resources as well as of present and potential uses. It administers the water laws and controls current uses, takes initiatives on development projects and discourages damaging and dangerous practices. The department must be a motor for a progressive water policy and needs farreaching legal powers to put its plans into practice, yet within the framework of ordinary legal procedure there must be the right of appeal to the courts against

arbitrary decisions imposed. The department or statutory body should be subject to the national planning board which mostly at cabinet level is responsible for the major economic and social decisions of a young country.

No general recommendation can be made on the extent of its duties as limited against other departments (for transport, agriculture, housing and public works, public health, economic development, geological survey, meteorology, etc.). Essential alone is an atmosphere of goodwill between the departments and efficient coordination. In water-short countries with ambitious economic development there is a forceful trend to unite under one roof all services connected with water; this is done at the expense of other legitimate considerations and may have to be balanced by an interministerial committee or a water board which is made up of representatives of the departments concerned which compete for the allocation of water resources.

A technical department in an underdeveloped area has to shoulder heavier responsibilities than an equivalent organization in industrial countries, as the design and construction branches can rely on the help of consulting engineers and engineering contractors for large works only. So design has to be done by government staff and most construction by departmental labour, and it is no easy matter — even under the most favourable of circumstances — to obtain suitably qualified personnel to fill all these positions. In addition considerable investment in construction equipment ist necessary.

2. *An Advisory Council on Water Affairs,* recruited from representative sections concerned with the utilization of water in its many aspects. This council ought to be established also on a regional basis in respect of each drainage area. In tropical and subtropical countries major decisions on water frequently impose heavy sacrifice or restriction on some members of the community. Therefore the public must be satisfied that at least the principal technical, legal, administrative, economic and social aspects have been discussed with independent experts and the vested interests before major new water allocations, particularly unpopular measures of some consequence or departures from the hitherto proclaimed policy are put into practice. The advisory body would create the necessary atmosphere of confidence, yet cannot claim to be a water parliament and hence does not interfere with the political responsibility.

3. *Legal Provisions* adapted to the requirements of up-to-date water development practice and giving to the government ultimate control over all water resources, yet with the proviso that expropriation is possible against fair compensation only. Modern water legislation may include the final departure from all traditional doctrines and the cancellation of all previous laws and ordinances by virtue of which it was previously possible to acquire water rights or licences or exercise direct control over bodies of water or discharge polluted effluents. Priorities by law are a severe handicap to economic development. There is relatively little difference in principle between up-to-date water codes for industrial countries and for developing countries of the tropical and subtropical zone, although a number of provisions may be different. No detailed model water laws would serve any useful purpose, yet it is quite conceivable that for a region a general section of a water code is developed into which the basic principles applying to all neighbouring countries could be incorporated, whereas individual countries could add their own provisions.

To ensure maximum efficiency of the schemes under review, aid giving countries should make cooperation for a progressive water code and a capable water development organization one of the basic conditions of any assistance agreement. A demand in favour of effective water legislation, put forward from outside at the appropriate moment, might enable many a government to make a stand against vested interests. Assistance in building up and training a water development service will be welcomed by governments of developing countries, provided the organization does not become an immediate burden of the budget. It is, therefore, essential that the water development service becomes quickly self-supporting by making pay all who benefit by improvements. Community water supplies, sewage schemes, hydro-electric as well as irrigation projects should be able to pay their way, but also a fair proportion, if not all, of the cost of flood protection and river training measures can normally be recovered.

The problem of finance is more difficult to solve where it concerns the longterm collection of hydrological data. Whereas mapping and geological survey operations as well as hydrological ad hoc investigations usually reach their objective within a limited period of time, the systematic observation of meteorological and hydrological events has to go on indefinitely. As this work is not spectacular and its necessity not easily understood, the fight for funds in connection with a basic data programme, including the running of experimental areas, may be difficult and its outcome uncertain. In view of future needs the establishment and training of a hydrological service including the implementation of a basic, well-balanced hydrologic network programme should have a high priority in the national development plan; successful examples exist of hydrological survey organizations being started and initially financed under a foreign aid scheme with the understanding that after two to five years the full expense is charged to the national budget of the developing country.

A serious hindrance to the establishment and smooth working of technical departments in developing countries are low salaries and favouritism. In countries where the colonial powers have left behind efficient services, a general mood of frustration induces the more ambitious members of the staff to leave; a foreign adviser or chief engineer is usually powerless to remedy the prevailing trend and in the face of poor morale build a well-trained technical cadre. In India and Pakistan effective services exist, but in most developing countries this problem is more serious than any other connected with water development. New irrigation projects in particular need constant supervision and advice on technical, economic and administrative aspects. Hence this especial dependence on qualified staff. Just in this field a promising solution has been found which deserves imitation. Ethiopia has granted concessions to a Dutch group to instal and operate irrigation schemes producing sugar cane; in Somalia and Afghanistan model irrigation farms have been established under Soviet management. Thus the developing country has its staff trained and an organization built which is left behind when at the end of the period of lease the schemes are finally handed over. A modified solution on such lines could be applied to other projects, but the department itself must be built under the final responsibility of its own government. Foreign agencies can sponsor its establishment and training, but the future of a national water development organization can be secured only by good pay and fair chances of promotion as a reward for efficient service.

Training of Staff

In his lecture on *"aspects of organization of a water development department — training of staff — international cooperation"* *L. J. Mostertman* analysed the traditional training of engineers in the different states of Europe and the fate of graduates returning after their studies to their old environment in the tropics or subtropics. The meeting identified itself with *L. J. Mostertman*'s conclusion that it is desirable that the undergraduate training of engineers takes place in their own countries or at least as near home as possible and in the same climatic and cultural region. For ordinary post-graduate training regional seminars and courses could be organized whereas for specialized courses on top level only relatively few institutions in the world are equipped. It was considered that the training of overwhelming numbers of "non-commissioned officers" for investigation, standard designs, construction and operation of projects, of skilled artisans, plant operators, water bailiffs, etc. is the most acute problem of technical instruction. Reference was made to the successful example of trade schools established and maintained by the German government; there can be hardly a better investment in the sphere of water development than to have such institutions multiplied thousandfold.

Special attention was given to the pitfalls of combining training and project progress on water development schemes. Participants voiced their opinion that effective training of technical executives is given only by making them shoulder responsibilities. Yet engineers from the developing countries trained on schemes are frequently looked upon as semi-official government representatives and treated with undue consideration. An improvement of training efficiency cannot be expected unless firms feel fully authorized to put these men to work as they do with their own beginners. The question of allocating the increased cost of a scheme in which trainees take part has not always been successfully solved.

Experts

The frequently discussed status and desired qualifications of experts also occupied the symposium. Unmistakable criticism levelled against the sometimes haphazard selection of advisers by aid-giving governments was summed up by the bonmot "an expert is a man far from his own country". Engineers and administrators, who have proved themselves at home, are suited for the part of adviser in a developing country only if they have had suitable experience in tropical and subtropical countries, if they are fair linguists and have demonstrated qualities of stability and leadership under difficult circumstances. The executives of developing countries are quick in spotting mediocre personalities. The principal reason why members of the former colonial services are acceptable as advisers even in countries with a strong anti-colonialist bias is that they represent an élite in respect of certain personal qualities needed for work in underdeveloped areas; their approach to the special technical and administrative problems is trained and frequently backed by regional knowledge.

The system of certain aid-giving countries paying the salaries of junior experts for several years' training on foreign aid schemes was much commended. As the number of experts suitable for work under the conditions of the developing countries is limited, aid-giving governments were asked by the conference to take steps to train a fair number of professionals for this aim. In countries like Germany the relatively small interest of civil engineers and scientists in work in underdeveloped areas is largely due to the fact that their future is not secured and that they find themselves at a disadvantage when on their return they try to enter the service of their own country. The French example is worth copying, as civil engineers who work permanently as advisers in underdeveloped areas remain members of the civil service and keep its privileges; in the Netherlands and other countries efforts are made to increase the establishment of the universities by several per cent for duty in developing countries.

Irrigation and Drainage

In the development plans of tropical and subtropical countries irrigation and drainage projects offer the only real alternative to industrialization by promising needed foreign exchange and providing for increased consumption of food and raw materials. Even countries where longterm industrialization is the aim, irrigation and land reclamation play a key role in satisfying increased food needs during the transition period.

A. de Vajda has drawn special attention to the fact that among all types of water development schemes irrigation and drainage require the most intensive permanent participation of large masses of the population. In any other water development project a limited number of staff is in charge of preparation, construction and operation; the necessary equipment can be largely imported. Irrigation and drainage works, however, need from the outset the full-time co-operation of the farmer or farm-hand for the maintenance of the fields, of the irrigation ditches and drainage, for the right application of water, the correct choice of crops and rotations: all these activities contribute to the economic success of the investment. Although irrigation and drainage projects can be put up by mechanical means, the daily handling of plants, of soil and water must always be left to the cultivator. Economic and technical aspects of this field of water activity are, therefore, very closely connected with the wider educational and social problems of the country. Details of design as well as of operation depend on the existing conditions and available skills to a far greater extent than in other hydraulic works. Increasing the efficiency of operation, education and technical training of the cultivators and their families is a major task, taking precedence of many others. Unfortunately it is frequently overlooked that effective land legislation, the establishment of rural extension services and of cooperative societies as well as improvement of credit and marketing, conditions must accompany irrigation and drainage schemes to ensure their success. Justified criticism has been raised against the system of employing engineers alone on planning and execution of hydraulic land reclamation schemes: this has frequently resulted in insufficient attention being given to important aspects, viz. soil science and agriculture.

In numerous developing countries more attention should be given to the improvement of existing schemes. This approach is perhaps not so popular, but would give a higher return on capital layout; equally the establishment of projects in countries with a tradition of irrigation farming is more advantageous than in areas which have to be introduced for the first time to the art of irrigation. Both groups of projects enjoy the tremendous advantages of an existing infrastructure which could be completed by relatively inexpensive complementary measures, viz., the improvement of repair and maintenance facilities. Also projects of more modest dimensions should be given preference to large projects. This choice has several advantages: the much smaller cost of the infrastructure, the lesser risk of expensive mistakes and the benefit of local initiative. The educational value of irrigation development step by step and the advantage of smaller projects yielding early returns deserve more consideration. Schemes reclaiming areas of several hundred thousand or even millions of hectares have in some countries become the outward symbol of the government's struggle to raise the economic level of the nation by a single deed. It is to be borne in mind, however, that such gigantic enterprises are usually expensive and need tremendous effort and sacrifice until the invested capital begins slowly to yield a clear dividend. Economic returns from irrigation projects are in most cases not sufficiently high to justify costly solutions — this principle must govern engineering design — and a return on the capital invested can be shown only if the infrastructure is provided.

Community Water Supply and Sewerage

The schemes grouped under this heading contribute most effectively to the building of an infrastructure for industrial, urban and rural development, but do not create by themselves additional sources of income. The supply of wholesome water for cleaning and other household purposes and the sanitary disposal of human and industrial wastes bring about an overwhelming impact on tropical and subtropical communities; they sharply reduce the incidence of death and disease, they raise the standard of living and inspire human dignity. Three-quarters of the world's present population is without a supply of drinking water which is reasonably safe and adequate; an even greater part of the population disposes of its excrements in a primitive and dangerous manner and water-borne diseases alone account in the developing countries for about one-half of the total illness and death rate. Yet the annual progress in the field of water supply and sewerage work amounts to only a small percentage of the rate of population growth. The vast back-log of deficiency remains untouched so far and the situation grows progressively worse. It is indeed difficult to understand that the governments of many developing countries in their quest of tapping new sources of income are inclined to concentrate their efforts on industrialization schemes to the neglect of their most fundamental infrastructure.

The combined effect of population growth, urbanization and industrialization is indeed so threatening that governments offering foreign aid should draw attention to the desirability of including a major proportion of such projects in investment programmes of developing countries. The International Bank for Reconstruction and Development has included a fair number of water supply and sewerage schemes in its investment plans. It is certainly a drawback that plant and pipes may have to be paid for in foreign currencies although in many countries locally produced pipes and fittings ease the foreign exchange problem. The total financial requirements of each individual scheme are relatively moderate, unless major impounding reservoirs have to be constructed. *H. G. Baity* has shown that the costs can be reduced without danger to the performance and safety of the project by a modification of normal technical standards in cutting out all de luxe equipment and in adapting the design of the plant and the construction works to prevailing climatic and labour supply conditions. Where money is scarce, facilities should be designed to provide service to as many people as possible rather than to give perfect service to the few.

Neither the original financing of schemes nor engineering design and construction offer the really disturbing obstacles in this field of activity. Jealousy and antagonism between various jurisdictions, the non-existence of a strong water department, unfair legal privileges under an outdated water code, woeful deficiencies in operation, maintenance and business management have in numerous cases either prevented the construction of schemes or caused their rapid deterioration and bankruptcy. It is essential to remember that enormous investments have gone to ruin as nobody knew how to run and maintain the facilities. The aidgiving countries should not limit their efforts to the technical side and the initial financing of the project but take an interest in the adequacy of rates, in the protection of the water authority against enforced contributions to the general budget and in easing restrictions imposed on borrowing powers for long term planning. Furthermore, no work should be undertaken on water supply and sewerage which does not involve the training of staff in managerial and administrative duties as well as in technical skills needed for operation and maintenance.

Allocation of Water Resources — Pollution Control

Due to the many claims on the water resources of a developing country it will become increasingly difficult to satisfy all needs. As a first step towards integrated river basin development a land utilization plan for the whole catchment should be sketched. Government should set up a single planning control authority consisting of all departments concerned with the economic and social development of the country. The general apportionment of water between different uses should be decided at an early date. Hydro-electric projects could be given a certain amount of priority as power may be the key to industrial development and water is a non-wasting asset.

In the interests of public health and industrial development the treatment of wastes, the conservation of the stream quality and the adoptation of far-reaching programmes in pollution control must be made a matter of high priority. It is essential that the developing countries are assisted to protect their water resources before it is too late. In this connection special emphasis must be put on adequate measures for the control of bilharziasis which has become a major threat to public health in tropical countries as a result of recent irrigation development. Every effort should be made to design and maintain irrigation works in a manner to prevent snail breeding and no such scheme should go into service without an accompanying programme involving the various measures to prevent infection and spread of this disease.

International Rivers

Water resources development on some of the economically most important rivers is severely handicapped due to difficulties between the riparian governments under whose sovereignties the catchment is divided. Much effort has been spent in recent years on persuading such governments to conclude international agreements, yet few attempts have been successful. On the subcontinent of India and in numerous other tropical and subtropical areas the absence of co-operation on international rivers leads to loss of economic and social opportunity. For developing countries a particular reason should favour early negotiations: there is the danger that riparian countries at a less advanced stage of economic development arrive too late to stake their claim, and it is always difficult to deprive another country of benefits which it has enjoyed for some time. The mediation of certain aid-giving countries and, above all, of the United Nations Organization and its agencies should be greatly welcomed. It has been found that the setting-up of common hydrological survey parties, investigating the water resources and drawing up plans for their utilization, has been a first successful step towards the settling of disputes.

V. Technical Considerations

Whereas discussions on principles of development policy showed a notable variety of views, representing all shades of the scale between almost implicit faith in the economic and social efficiency of water projects approved by government and, on the other hand, cool analytical detachment, an astounding unanimity of thought on most technical issues pervaded the meeting, irrespective of the professional or local origin of the speakers. None of the technical sections of papers gave rise to differences of opinion; discussions purely enlarged on experiences and set new and sometimes unforeseen accents.

Under different technical headings reference was made to the following characteristic problems which severely complicate economic solutions of technical projects:

1. Absence of good topographical, geological, ecological and soils maps and of precipitation and hydrological data; and the need to obtain them without delay.
2. The need of adapting technical solutions to the physical conditions of the tropics and subtropics.
3. The added difficulty of planning optimum development of water resources and of designing economic capacities of hydraulic works in areas where the general trend of the economy is less distinct and final than in the more established regions.
4. Economy in expensive or imported construction materials, viz. steel, cement, seasoned timber, galvanized iron piping, the unrestricted use of which in the wealthier countries has been a condition of technical progress; economy in imported machinery and mechanical devices.
5. Work with insufficiently qualified or even unskilled personnel of all technical levels. Foreign consultants in small numbers can be called in to solve special hydrological, geophysical, hydraulic or structural problems; yet skilled mechanics for the maintenance of machinery and staff for the construction of drainage and irrigation projects, for pre-stressened concrete work or the running of thousands of water supply and sewage disposal schemes cannot be trained in a short period of time.

6. The labour conditions imposed on construction work: in countries suffering from population pressure and unemployment there is a permanent social necessity of using manual labour on a large scale, whereas in under-populated areas the need of mechanizing construction methods on a tremendous scale arises.
7. The complete absence of an infrastructure in certain under-developed areas: lack of communications, of power, of hygienic water supplies, of public health facilities and schools.

The following paragraphs give an evaluation of the technical lessons of water projects as affecting foreign aid policy; they are a summary of essential technical points made in papers and discussions which have led to the passing of recommendations.

Procuring Basic Data at Short Notice

Of all technical water problems in developing countries the absence of long range hydrologic records represents the most disturbing handicap to swift development. It causes uncertainty and leads to uneconomic investment in all branches of hydraulic engineering work. Whereas mapping operations and the collection of hydrological, geological, geophysical and pedological data can normally follow a certain established routine, the individual procedure of reconstructing the long term behaviour of the hydrologic cycle purely by analogy, by extrapolation and by the evalution of clues has to stand every time the hard test of future events. *A. Volker*'s paper gives the gist of *recent hydrologic experience,* making special reference to the unit hydrograph, to the part soil moisture determination can play and to the depletion curve. In adopting a recommendation the meeting stressed the importance of making the establishment of a hydrological organization, of hydrological networks and of experimental areas a high priority project within the social and economic policy of developing countries.

E. Gigas's comprehensive survey of the *latest mapping methods* to be employed under pressure of time should give to the water development specialist an eminently useful idea of how to cope with cartographical gaps. An outline on photo-interpretation has been added, a subject of growing importance, particularly for hydrological investigation and the design of irrigation and drainage systems. After discussing *E. Gigas*'s paper the meeting inter alia recommended that air-photography should make allowance for as many technical interests as possible and that before flights are begun, hydrological, geological and agricultural needs with regard to scale, flight height, and extension of the overflown area should be considered. For mapping operations air-photography should be used to a larger extent in future.

H. Kleinsorge, of the Federal Institute of Soil Science at Hanover, and his colleagues *H. Flathe*, *O. Strebel* and *E. Schönhals* have contributed a paper on the scope of *geology, geophysics and soil science* for planning and preparation of water projects in developing countries. It gives the technical strategy of dealing with such problems, claiming that modern approaches to solutions in this field demand a high degree of specialization which can be obtained by team work only. A recommendation on geology and related subjects stresses their importance for the planning of all major water development schemes. It draws attention to the need of joint hydro-geological and geophysical investigations for the development of groundwater resources and to the part which pedological surveys should play in future hydrological and water development schemes. The establishment of more pedological investigation centres in proposed irrigation areas of the arid and semi-arid zones was also recommended by the meeting.

The preparation of most water development projects demands numerous meteorological data; ecological maps can be an efficient help for hydrological extrapolation and for irrigation and drainage schemes. Due to shortage of time the symposium had to refrain from dealing with both subjects. On the scope of plant ecology for the benefit of hydrological investigation in tropical and subtropical areas an eminently useful discussion could still be held. On hydrometeorology WMO has issued a number of publications. A committee is preparing a "guide book" which will also include a standardization of methods for the collection of hydrological data and for special hydrological investigation work.

Adaptation of Technical Solutions to Special Physical Conditions of the Tropics

The characteristics of the hydrologic cycle in different tropical and subtropical zones and water management techniques to overcome long dry periods, high rates of evaporation and poor groundwater recharge have been frequently discussed in technical literature. In this section reference is made to other phenomena only.

L. J. Tison summed up his survey on *erosion and sediment transport*, that tremendous problem which in particular concerns tropical and subtropical countries, by stating that we are still at the beginning of finding solutions and that up to the present the staff concerned with anti-erosion measures is too small and not sufficiently organized.

The meeting stressed the need of silt investigations which must complement construction work where the life of storage basins may be shortened by a silting-up process. FAO is devoting funds and energies to its anti-erosion programme.

Khan Mohammed Azam in describing *flood control and river training problems in Pakistan* drew attention to difficulties common to Southeast Asia where the low lying country is threatened by tremendous flood flows from inland and by catastrophic inundations from the sea. Too few data have been collected in the past; large scale flood defence measures on the Ganges and the Brahmaputra are still in their infancy and have to proceed step by step; practical work is so far restricted to embankment construction, channel improvement and local flood protection projects. Effective flood control on the main rivers can be achieved only by international cooperation with India and China.

In a discussion led on by *L. J. Mostertman* the peculiar problems of river training for inland water transport in respect of shallow, silt laden waterways of the tropics and subtropics were described and detailed reference was made to the proceedings of the 20th International Navigation Congress in Baltimore[2] which had thoroughly dealt with this important subject. Permanent structures for river training in the interests of transport and recurrent dredging operations on a large scale are economic in but few river reaches outside Europe and North America. On medium-sized tropical waterways of poor navigability the employment of temporary structures for the deepening of the channel by the force of the water stream is recommended as a cheap solution. Special reference was made to scouring barges, using *Potapov's* method of helicoidal flow to cut channels through crossings and flats during the low water period; such special hydraulic measures should be combined with a system of effective channel patrol. Whereas this method has been successful in West Africa, doubts were raised on its unmodified application on the large rivers of Southeast Asia.

It was stated during a further exchange of experiences that traditional skills and local methods depending on the availability of special local materials have been applied to minor or medium-sized river or coastal protection works in many parts of the world. They are similar in principle to those which have been developed in dif-

---

[2] See the contributions of L. van Bendegom, N. Domanewsky, M. Rousselot and M. Chabert, H. C. Frijlink and others to the 20th International Navigation Congress in Baltimore, 1961, published by the Permanent International Association of Navigation Congresses, 60, rue Juste Lipse, Brussels 4.

ferent regions of Europe during former centuries and are dealt with in handbooks on river training. Some of the methods used in South East Asia as described in ECAFE publications[3] are well suited to other areas with similar needs, yet up to now without a tradition of flood control and river work. The transfer of such skills depends on the training of workers either at a European centre or on suitable construction sites in the ECAFE area. These simple but effective methods can be further improved by applying modern methods of soils stabilization. It was recommended that the authorities should encourage the plantation of brushwood and reeds along the rivers.

Coastal problems were not specially discussed by the meeting. The subject has been dealt with by the Regional Symposium on Flood Control, Reclamation, Utilization and Development of Deltaic Areas, held in Juli, 1963, by the Economic Commission for Asia and the Far East which will publish its results in its Flood Control Series.

Economy in Imported or Expensive Construction Materials and Mechanical Equipment

Shortage of funds, of foreign currency and power and the frequently inflated cost of projects due to the absence of hydrological data recommend the use of relatively cheap local construction materials. Only a few examples shall be given. *K. L. Rao* mentions in his paper *"characteristic demands on design and construction of major works in less developed areas"* savings made on the Bhakra Dam by using a smaller cement content, grinding shale to the fineness of cement and adding it to the concrete mixture. This measure has replaced between 10 and 20 per cent of the cement normally needed. In most countries of the ECAFE area as also in certain other parts of the world the traditional skill in stone masonry work can be utilized to great advantage; this requires departures from European design standards.

Exemplary masonry dams of all sizes have been completed in India and Pakistan during recent years. Earth dams are still cheaper than masonry structures and recommend themselves to most developing countries. All such measures, however, demand the services of up-to-date laboratories to test the strength of local construction materials; and unless such tests can be taken, savings are hardly ever achieved. Lack of modern mechanical equipment due to shortage of foreign currencies greatly complicates work on a construction site.

---

[3] Methods and Problems of Flood Control in Asia and the Far East, Flood Control Series No. 2, Bangkok, 1951. — River Training and Bank Protection, Flood Control Series No. 4, Bangkok, 1953.

On irrigation canals brick lining can be used to replace concrete, or instead of any lining the canals could be designed to larger dimensions, if no major water losses occur. The employment of imported automatic gates and modules on irrigation works, so necessary for a firm control of water, is frequently prohibitive owing to the relatively low market value of the crops under irrigation. Attempts are being made to replace small mechanical devices by locally made, simpler types.

H. G. Baity in his paper on *community water supply in the developing countries* shows how in the interests of economy normal technical standards of water supply and sewage disposal can be modified without danger to their performance or safety. Very considerable savings — up to half of the expenditure needed, if European criteria are applied — can be made by cutting out unnecessary equipment, by adapting the plant to the prevailing local conditions and by leading supply lines to central water points accessible to many users.

Shortage of Skilled Staff

The availability of skilled technicians of all grades influences design, construction and operation of schemes. Without the possibility of servicing mechanical appliances on the construction site their utilization must be discouraged, yet several construction phases and activities cannot entirely dispense with machinery; this applies to the dewatering of excavations by strong pumping units, the closing of the last gaps of weirs or dams against a strong river current, and also to urgent flood control works during the relatively short dry seasons as claimed by *Khan Mohammed Azam* for East Pakistan, where in spite of the unemployed surplus of unskilled labour strong bulldozers have to be brought in, pick-and-shovel workers not being sufficiently fast to complete the job before the onslaught of the next monsoon. Also the construction of large earth dams cannot be carried out without the use of earth-moving machinery. It is perfectly possible to follow a policy of restricting the application of machinery on construction sites for yet awhile; but major projects in developing countries will need increasingly the support of mechanical appliances.

K. L. Rao has given a number of examples how technical designs depend on the skill of the available construction and maintenance staff. Although shell roofs and pre-stressing techniques are highly economic, they can be applied in less developed areas only in very exceptional cases owing to a high standard of local labour and supervision needed for the execution of such designs. Trained staff for grouting operations is rarely available, and so excavation for foundations must go down to bedrock, a measure which often raises the cost of a project very considerably.

A. de Vajda in his paper on *"factors influencing planning and operation of irrigation and drainage projects in developing countries"* shows to what large extent the system and all major and minor features of irrigation and drainage depend on the skill of the construction staff and of the cultivators, but also on the availability of maintenance facilities of tools and appliances. The simplest solutions wise desirable automatic devices are extremely vulnerable if not check-can only be recommended where the mechanical equipment can be properly serviced. The use of tube wells should be restricted to areas where pumps and engines can be maintained and where sufficient supervision is exercized to avoid overpumping. The design of control gates for reservoirs, for regulators, spillways, offtakes and aqueducts must be adapted to rough handling and poor maintenance. Simple and strong structures, easy operation and the least possible need of maintenance are the only guarantee for smooth working of irrigation and drainage systems in areas with unskilled operators. Various otherwise desirable automatic devices are extremely vulnerable if not checked regularly by capable staff. Where no efficient supervision can be given to in situ construction of minor structures, prefabrication is a distinct advantage, provided transport can be obtained

Infrastructure and Construction Practice

A. H. Naylor in his paper on *hydro-electric and integrated river basin development in underdeveloped countries* which offers much detail, explains inter alia how deficiencies of the infrastructure are to be considered in the design and construction stages of major works. The size of the power units to be installed, the running of the construction site, the rate of progress and the efficiency of the scheme depend on accessibility and initial power supply.

In the field of irrigation the lack of good communications makes the adoption of highly effective and expensive solutions difficult; also principal features of design and construction for even small community water supplies depend on the solution of the transport problem.

This report is essentially one of policy and cannot attempt to evaluate in full the large number of excellent technical contributions. A supplementary publication may take more detailed account of the technical lessons of water development in different branches of hydraulic engineering as presented to the symposium.

VI. The Lessons of Water Development as Affecting Foreign Aid Programmes

Effective foreign assistance in the field of water development can be given under the following headings:

1. Projects of technical aid; training of local staff.
2. Research and investigation work in the interest of water development.
3. Assistance through the United Nations.
4. Capital investment and loans.
5. Temporary concessions to foreign organizations.

Each type of aid has its own opportunities, problems and pitfalls and should be treated separately here.

Projects of Technical Aid; Training of Local Staff

Technical aid for water development covers a wide range.

Basic data for the preparation of schemes are among the most acceptable contributions to be made. The papers by *A. de Vajda, A. H. Naylor, H. Kleinsorge, E. Gigas* and *A. Volker* deal with this aspect and state requirements with regard to the various preparatory surveys. Equally technical designs and advice on the more difficult phases of execution as well as supervision of contractors offer welcome scope of technical aid, especially if such activities are of a highly skilled character. Free capacities in the hydraulic laboratories of the European technical universities could be employed to a far larger extent where no local institutes of this character in the developing countries are available as yet.

Technical aid should be given only if it is valued. Sheer thoughtlessness — in many cases unsurmountable political antagonism among aid giving nations — must be blamed for a deplorable lack of coordination and even for competition between separate technical aid efforts in water development work. It is necessary to convince a recipient government that its reluctance to establish a minimum of cooperation between the aid giving agencies working within its territory deliberately encourages duplication of work and defeats the object of foreign assistance; and that in the present scheme of things the final impact of such aid on the development of the country depends on the government's own ability to make the best use of the help provided. Benefiting countries would be well advised to make available the basic data obtained by one project group to the other agencies working on similar problems, a measure which would greatly enhance the value of the work to all. The United Nations agency closest concerned might be enlisted to mediate in favour of such cooperation.

No technical assistance project should go forward without a detailed plan how genuine cooperation with local staff and its training in all phases of the work can be put into practice. Such cooperation on engineering works which are subject to a time schedule of progress and to a narrow margin of expenditure raises delicate questions which must be settled with tact and understanding. On balance only such technical aid efforts count for the future which train and inspire local personnel to act as nuclei for new programmes. There is so much work to do in all branches of water development that the developed nations could never attempt alone to prepare, construct and run more than a minute fraction of the schemes which will need urgent implementation within the next ten or fifteen years.

Non-technical difficulties are at the root of most incidents of technical failure. The need of setting institutional matters right before embarking on water development on a large scale — especially by creating a modern water code and by establishing an effective water development department — has been dealt with in section IV. There is excellent scope for technical aid in this field, but responsibility for the setting up and the training of an organization entails the solution of problems beyond the normal scope of technical work and in certain cases may require a partial reform of the administrative structure. In most developing countries speedy action is needed to remedy the general state of frustration among the technical services, resulting in the more valuable members of the staff getting lost to the department. Favouritism, unreasonably low rates of pay compared with the non-technical services, lack of authority, frequent transfers which make specialization impossible, and other genuine grievances deserve careful study and effective measures. The case for a revolutionary reform of certain public service concepts as found in many of the developing countries must be strongly put, before it is too late. The outcome of this issue will finally settle whether there shall be continuity and efficiency in the service. An aid giving country taking responsibility for the setting up of a department, for the training of technical staff or for contributing to the capital cost of a scheme must insist on this aspect being given priority in the assistance agreement. Conditions, scope and efficiency of the technical services should be investigated and recommendations made; implementation of the necessary measures must be ensured prior to the engagement on expensive schemes.

Assistance to technical schools at all levels in the developing countries is preferable to giving basic technical education in Europe and North America to students from overseas. Projects for trade schools with workshops attached and medium grade technical schools should be given priority. If the training is to take place in Europe, the graduate should start practical work in his own country under the tutelage of an adviser who is connected with the training scheme in Europe. Thus the practical training and specialization — although based on local technical problems and methods — would correspond to the syllabus of the university which the student has attended. It appears that the possibilities which follow-up projects offer for the improvement of the beneficial effects of training programmes have been applied to engineering students in exceptional cases only. If a policy on these lines were adopted, it would demand close cooperation with the water departments of the developing countries and territorial restrictions self-imposed by each European government working in this field. An understanding between the various aid-giving countries on this matter would be required.

More attention should be given to the training of water development experts who have not served in the less developed areas under the guidance of first-rate and experienced men. Especially arranged university courses could impart the knowledge of technical methods which have been adapted to meet the requirements of developing countries.

The problem of selecting suitable civil engineers for overseas duty on water projects could probably be solved, if aid giving nations would decide to increase the establishment of their own hydraulic engineering and water development services by five to ten per cent above their present strength. A proposal on such lines may be none too popular with the national treasuries and parliamentary budget committees, yet it would put technical assistance work on a solid footing and prove to be a generous contribution to the concept of foreign aid at a very moderate price. The chances of technical staff to serve abroad for a term of duty would make government service more attractive; on the other hand holders of posts who should consider early redundancy in their respective overseas functions to be one of the primary objects of their efforts deserve a measure of social security.

Research and Investigation Work in the Interest of Water Development

In a number of cases it is more efficient for aid-giving countries which dispose of highly trained staff with scientific understanding and technological skills to put some of their available funds into research of essentially troublesome problems or into the badly needed development and design of appliances and methods, instead of investing the same amount of money in direct projects. In hydrology, hydraulic engineering and adjoining disciplines there is ample scope for such activity, viz. reducing the rate of evaporation of open water surfaces; establishing in areas of high rainfall suitable plant societies which are satisfied with a fraction of the available moisture and leave the balance to recharge the water table; devising anti-erosion measures which can be applied to all types of soils and are within the financial means of a poor country; improving silt sampling methods; producing a cheap and reliable currentmeter which does not need occasional calibration; improving methods of hydrological investigation and of soil moisture analysis; designing simple and cheap automatic irrigation devices; finding solutions to the salinity problems for the benefit of areas which have gone out of production; developing sets of standard drawings for community water supply and sewerage works to comply with conditions of certain climatic regions.

However, problems of water development are by no means limited to the technical plane. Highest priority ought to be given to surveys of the economic and social impact of schemes on the developing countries; another set of investigations should be entrusted to teams of anthropologists who would have to test which social and educational patterns can adopt certain new technologies. All research and development work of this kind should be carried out in liaison with the international organizations which may be aware of the latest developments in this field.

Assistance through the United Nations

Repeated reference has been made in this report to the beneficial effects which the activities of the United Nations and their special and regional agencies have had upon the more important aspects of water development. In certain branches of hydraulic work, including irrigation projects and community water supply, the United Nations have become the specialists par excellence for the less developed areas. The Conference agreed that in the field of water development the United Nations are very successful and that sacrifices of funds and technical personnel to support these efforts are eminently worth-while.

Capital Investment and Loans

On behalf of representatives from the developing countries *K. L. Rao* made an impressive plea in favour of large scale capital assistance for major water development projects, and there was general agreement on the need of providing foreign exchange for the purchase of workshop and construction equipment, of expensive construction materials, of machinery, etc. Yet a strong warning against "handouts" in respect of water projects was reiterated by all who by virtue of their international experience of long standing have had the opportunity of following up the fate of schemes presented as free gifts. In many cases donors were forgotten and the undertakings not as well looked after as those for which heavy sacrifice had been imposed on the community benefitting by the project. To make certain that a water development scheme is treasured and adequately maintained by the receiving community, *H. G. Baity* suggested that not only a relatively large number of local personnel is engaged on all levels and in all successive phases of the work, but also that the country bears in each case a substantial part of the financial burden.

Our growing experience proves that the absorption of water development schemes into the organism of a new country is not as simple as optimistically assumed by international political opinion. The close dependence of the economic success of projects on favourable circumstances — institutional, infrastructural, educational — and on careful preparation going beyond the purely technical has not always been sufficiently considered. This knowledge should not detract from the potential economic and social dynamism of water programmes, nor discourage strenuous efforts to finance new projects, yet it ought to serve as a warning that progress cannot be measured by the number and size of the technically perfect hydraulic structures completed.

It is essential for the consideration of proposals concerning technical work in developing countries that the place of the project in the national effort should be clearly defined. As long as there are no surveys in retrospect which may create a new tool of economic analysis, capital aid projects ought to be dealt with according to the procedure recommended by *Gilbert F. White* and analysed in section III of this report.

A realistic review of water projects in the preparatory stages of capital assistance is often complicated by the urgency felt in low income countries to get major works under way. Public opinion which prods governments to attack social distress and get something spectacular done, may dictate action that does not meet reasonable criteria; the issue is frequently aggravated by enthusiastic commitment which builds up around particular projects. In dealing with such situations it could be more economical and speedy to hold up decision, until the missing social, economic and technical surveys are completed, than to move ahead hastily with construction. Although a decision on projects is usually seen as being either negative or positive, there are often attractive alternatives to immediate constructive action. By offering to fill in first some of the major institutional and infrastructural gaps, the prerequisites of economic success in respect of water development activity can be prepared before the green light for projects is finally given. It may also be feasible to begin with pilot schemes or the elementary stages of large projects. Suitable technical aid measures which could be offered as another alternative promise sometimes earlier and larger returns than capital investment. The urgency of gaining new income may be an argument in favour of small programmes with early returns over large new projects which will require many years to reach final completion. Such cautious beginnings need not prejudice ultimate development.

Temporary Concessions to Foreign Organizations

This type of assistance, which can be invaluable for the training of staff on management and maintenance and should result in handing over at the appropriate time a going concern, is still in its experimental stages. *A. de Vajda* has referred to its possibilities with regard to drainage and irrigation schemes, but it may be suitable also to community water supply, hydro-electric projects and to river training for the benefit of inland navigation.

The symposium asked for improved liaison between national and international agencies concerned with water development projects as an essential part of their foreign aid policy; closer cooperation between various types of assistance programmes, particularly between capital and technical aid, was recommended.

This summary is largely a tale of problems and difficulties from which the reader might gain the impression that the resulting note of the symposium was one of qualified discouragement. Nothing could be further from the truth, and no better motto could be chosen to sum up the mood of the conference than *K. L. Rao's* saying: "Put to proper use, rivers are veritable treasures and perpetual banking houses . . ."

VII. Postscript

It is appropriate to round off the analysis of a conference by asking whether its object has been attained. What, in fact, has been achieved, and how are the remaining gaps of our knowledge to be closed?

The Foundation had put two questions to the meeting, both of which were answered. The first problem concerned itself with the need for a sufficiently reliable technique of decision making; by suggesting certain questions to be asked which would link a water development programme to broader national aims, it is thought that the full implication of the work to be undertaken should now be understood by the government agencies concerned. The second item on the agenda asked for a summing up of general principles and technical methods of water management in the developing countries, to serve as background knowledge for a foreign aid policy in this sector; such evaluation of experiences has been dealt with in papers, recommendations and, finally, in this analysis. Never before an equally representative assembly -- representative by virtue of its worldwide experience and territorial origin, and by its diverse professional interest in the numerous branches of hydraulic activity — had grappled with these questions; so the lessons of this Conference may be of almost universal application to water development in the less developed areas and, in their approach, of use also to other provinces of foreign assistance work.

Repeated mention has been made during the symposium of numerous particularly troublesome problems concerning almost all branches of water development activity in the tropics and subtropics, and very considerable funds and much scientific skill are needed during the next few years to push on with research and related activities on a wide front. Before such progress is achieved, however, there is immediate and urgent scope for a second meeting to extend the results of the first. Two items are recommended for its agenda.

Firstly, the developing countries should be treated one by one and the general conclusions of this Conference directly applied to the requirements of foreign assistance in each case. A representative delegation from the international experts attending the first conference with worldwide local knowledge would be able to fill this gap without much difficulty.

Secondly, the discussions on water programmes and their place in the national effort brought home the fact that if water development is to remain one of the principal tools of foreign assistance, the social questions related to it require greater attention. One of the remarkable aspects of the discussions of the Conference was a general acceptance of the fact that our technical and administrative proficiency in planning, execution and operation of engineering projects in the less developed areas far exceeds our knowledge how by designing the essential social and economic measures full effectiveness of the expected benefits is to be obtained. This statement applies more or less to all aspects of water development. As *Gilbert F. White* and *A. de Vajda* have pointed out during the Conference, it is not uncommon to exercise great sophistication and precision in the design and construction of a dam and the distributory canal and drainage works, but to give only passing attention to the required changes in land tenure, to agricultural credit and marketing facilities, to the organization of village life and to the system of elementary education. However, it is essential that these aspects are taken care of, if full use of the planned works is to be obtained. An enquiry made since the end of the symposium has brought to light that observations have been made very recently in various parts of the world on what would seem to be the necessary social and economic measures to accompany technical projects. No careful assessment of the results of such studies and of the possibilities of their application to future planning has been made. A concentration of such experience is not to be found at one place, yet attention to different aspects of this complex is being given at several centres. There is a fair chance that by bringing together some of the economists, geographers, anthropologists, sociologists and agricultural economists, who are most active in dealing with these economic and social problems in the developing countries, with experienced civil engineers and administrators our unterstanding of the impact of engineering schemes on their environment would move a sudden step forward.

C. Papers Presented to the Conference

I. Water Development as Part of a Development Aid Policy

by Gilbert F. White

Water Management has occupied such a prominent part in economic and social development efforts during recent decades that to assert its vital importance may seem a truism. In the four most populous nations — China, India, the United States, and the U. S. S. R. — hydro-electric power, irrigation, navigation, and flood control claim a sizeable sector of public works construction. The development plans of many low-income countries have included heavy commitment to water projects. During India's first five-year plan water projects accounted for 28 per cent of total expenditures, and in the next plan for 19 per cent. In Pakistan's second five-year plan about one quarter is allocated to water. Among long-term investment programs prepared by International Bank missions for 15 nations during the past fourteen years water projects, including urban water supply and waste disposal, amounted to from 3 to 42 per cent of the total recommended expenditures (see Table I). All but three were in the range of from 15 to 36 per cent. Of these suggested amounts the expenditures for urban water supply and waste disposal commonly ran from 1 to 6 per cent of total capital investment.

At the same time, the technology of design of water-control works on large rivers as well as small tributaries has advanced with sufficient breadth so that certain aims and criteria of water development are rather widely accepted across national boundaries. There is a remarkable agreement among engineers on concepts of multiple-purpose projects, integrated basin development, and criteria of economic efficiency for project evaluation. While displaying interesting differences form area to area, forms of dam design, basin schemes, and economic justification are much alike. One does not find the sharp differences that mark methods of economic planning, the philosophy of public education, or systems of community co-operation and constraint. There is a kind of concensus that transcends national boundaries.

Table I

Water Development in Capital Investment Programs Recommended by I. B. R. D. Missions[a]

Country	Per Cent Capital Expenditures in Water Development		
	Urban water supply and waste disposal	Other: irrigation, drainage, hydro-electric, flood control	Total water
British Guiana	1	21	22
Ceylon	4	32	36
Guatemala	7[b]	25	32
Iraq	9	33	42
Jordan	4	13	17
Libya	6	12	18
Malaya-Federation	7	7	14
Nicaragua	5	2	7
Nigeria	?	7	?
Surinam	6	26	32
Syria	1	20	21
Tanganyika	3[b]	16	19
Thailand	0	23	23
Uganda	2[b]	1	3
Venezuela	6	9	15

a) Estimates from reports prepared by missions of the International Bank for Reconstruction and Development during the period 1951—1962 and published by the John Hopkins University Press. The expenditures are those recommended by the missions for 4 to 10-year programs, and represent their judgment of a desirable balance of investment.

b) Rough estimate from report.

Certain of the concepts now receive at least lip service on a broad front of activity and have been described more precisely elsewhere (United Nations 1957, 1963, E. C. A. F. E. 1955). These are the following:

1. Wherever practicable plans for water development should be drawn for basins as a whole or for areas comprising common sources of ground and surface water.
2. Individual projects should be designed to take account of all possible purposes which can be harmonized on technical and economic grounds.
3. Measures for water regulation in streams and aquifers should take due account of possible effects of water management in field, pasture, and forest.
4. Individual projects or systems of projects should be undertaken only if the anticipated benefits exceed the expected costs.

Methods of economic analysis have been refined, and the art of basin planning has advanced (Maass et al. 1962; Weber and Hufschmidt 1963; F. A. O. 1963).

In some sectors of the world a graceful concrete dam is as important a status symbol as a sleek, black motorcar, a shiny nuclear reactor, or the blinking dials of an electronic computer. Any self-respecting minister of public works must have at least one in a visible place. In certain areas, regardless for the present of its material size and benefits, the monolithic structure also is an emblem of united effort for economic growth, and it yields social returns as an organizing concept that goes beyond its ordinary direct returns in income or productivity.

This widespread acceptance of both the desirability and general method of water development is heartening to those concerned with such programs, but it also carries a severe disadvantage in that it tends to be regarded as a good thing without receiving the critical evaluation it deserves. All too often public funds are committed to water use and control on mistaken assumptions as to the economic harvest to be reaped and as to the conditions necessary to assure it. These assumptions are less likely to go unchallenged when water development is planned in conjunction with other sectors of public works or with a national development policy, as, for example, when a single capital budget is prepared or when a long-term external aid and development program is proposed.

It may help to provide a framework for the technical discussions which follow this paper by stating two simple propositions as to the relation of water management to development aid policy and then illustrating them with six concrete problems. The first proposition is that efficient design of water management as a tool of economic development requires definition at several points of aims and criteria which rarely are within the competence of the engineering designer and should come from broader development policy. The second is that these critical aims and criteria are likely to be accepted without public discussion upon the basis of unintentional, often unconscious, and frequently oblique decisions that are woven into technical design.

Before illustrating these propositions two qualifications should be made. The most important is that notwithstanding the heavy investments in water projects over recent decades there has been virtually no thorough appraisal of the full social, economic, and physical effects of major water schemes. We have data on area irrigated or kilowatt-hours generated or changes in stream stage, but remarkably little as to project impacts upon both the natural and social environment.

Thus, the Tennessee Valley Authority has achieved a high degree of river regulation, power production, and soil conservation at relatively low cost, but we cannot say with any certainty that the per capita income of the people of the valley has been raised by a certain magnitude in contrast to nearby areas not having the same type of development. Only a little is known concerning the net social returns from irrigation investment. The influence of new works upon water and sediment flow downstream is still doubtful in many areas. There are several reasons for this ignorance as to the accomplishments of water management to date: the time has been so short in many cases that it would be premature to draw conclusions; in others there has been a disposition among administrators controlling the pursestrings to concentrate upon future work rather than to pry into past effort at the risk of uncovering disappointment and failure; and even where there is time and desire to assess the past the analytical methods for determining impacts are so rough in some sectors that only gross assessment can be made.

To indicate more precisely what is lacking I will cite a few studies which do give us quantitative estimates of certain effects of water management. Income redistribution effects of multipurpose power projects have been traced for parts of the Columbia Basin (Krutilla and Eckstein, 1958). The consequences of land colonisation schemes have been assessed for the arid sector of Ceylon (Farmer, 1957). Economic costs and benefits of irrigation, and the social change stemming from economic growth have been measured in a few Indian projects (Gadgil, 1948, Epstein, 1962). The change in flood losses in connection with flood protection investment has been estimated for the United States (White, 1960).

Although here and there the studies are sufficiently precise to permit solid conclusions, much of the appraisal still is in the domain of seasoned and qualitative judgment by men who have been involved in water development. My own acquaintance with such work has been chiefly in the United States, with slight exposure to projects in Africa, the Eastern Mediterranean, and, more recently, Southeast Asia. Much of the statement of problems that follows is drawn from experience in the United States or the Lower Mekong.

Defining the Development Aims

A theoretically complete management of the waters of a surface drainage area or an underground basin would so regulate flows and withdrawals that the full safe yield and fall of all water would serve optimum social needs. This never is attained except in an arid basin where all available waters are used efficiently for consumptive or dilution purposes. Moreover, the harnessing of flow is not in itself a desirable aim: it is significant only as it advances prior social aims. These cannot be defined with any validity if stated only in terms of water management. It is not enough to speak of "increasing the irrigated area" or "reducing flood damage" or "providing a large block of cheap power" or "improving low cost water transport". To have definite meaning for planning each of these aims must be based upon social objective and criterion.

Take as an example a proposed increase in irrigated area. This might have as a more basic aim any one or combination of the following:

1. Increase in agricultural production to meet domestic demands for foodstuffs, as in India.
2. Increase in marketable output of a cash crop to maintain foreign exchange, as with cotton in the Sudan.
3. Increase in stability and level of living of peasant farmers, as with small projects for Africans in Southern Rhodesia.
4. Stabilization of livestock grazing industry, by providing forage for adjacent grassland areas, as with parts of the upper Colorado Basin.
5. Sedentarization of nomadic grazing population, as in the Helmand Valley of Afghanistan.
6. Satisfaction of peasant demands for land, as in Ceylon.

Others might be listed, but let us accept these and indicate the types of criteria that might govern design of a project to meet one or more of these needs.

They could include:

1. Maximization of total product — leading to an expansion to the limit of marginal costs.
2. Maximization of net social returns — leading to optimization of size at that yielding largest marginal returns.
3. Minimization of possible social cost in dry years — leading to largest coverage of areas of crop risk.
4. Maximization of rate of social change — leading to revolution in ownership, tenure, and cropping practices.
5. Minimization of social change — leading to preservation of the status quo.

The same obvious range of aims and design criteria can be applied to other purpose of water management. Depending upon the aims and criteria which are selected, the design of a resulting irrigation project may vary tremendously in the area covered, the crops and crop practices contemplated, the lands irrigated, the reliability of supply assured by storage works, the complementary works planned, and in numerous other ways. Sometimes these aims and criteria are stated explicitly. All too often they creep into the study without challenge, and are either accepted by the engineers without questioning their probable implications, or are adopted as a part of development policy without considering the alternatives.

The remedy is a continuing, reciprocal exchange of views and preliminary findings between those doing the water planning and those concerned with broader economic and social goals. Where this is not achieved, the final water plans may go far wide of those goals.

Water Management versus other Methods

Because technicians responsible for water plans are charged with that task and have little occasion to design other methods of meeting the same aims they may ignore cheaper, more effective alternatives outside the province of water management. Conventional engineering solutions tend to dominate public thinking; they are accepted without painful explanation, they seem to involve less risk of failure, they lend themselves more readily to centralized government direction.

Let us list some examples. Where increased foodstuff production is a dominant aim it may be that while irrigation would be essential to obtaining maximum returns under available technology, substantial gains could be reaped more quickly by investment in seeds, fertilizers, pesticides, or other inputs. In the Lower Mekong, irrigation and flood control will be needed before farmers can be expected to adopt some of these improvements, but it also is possible that over a period of a decade rice production could be raised significantly by other means at much lower cost per ton of increase.

In the United States we are learning that regulation of the use of flood plains and advice on means of rendering buildings less vulnerable to flood loss may in some valleys be more effective in curbing certain flood damages than dams constructed upstreams. Flood loss reduction is seen as involving both engineering and non-engineering measures.

To the extent that integrated planning of transportation and energy supply networks can be obtained, it may well be that a proposed waterway, even though shown to be warranted as a single-purpose improvement, may be less effective than alternative pipeline and rail construction, or that a promising site for a hydro-electric generating station may be in fact more costly than a fuel-electric plant at tidewater.

If the stabilization of livestock activity or of food supply in drought-hazard areas is a principal aim, a system of forage stores, or livestock transport, or income insurance may prove more effective in reducing drought dislocations than would an irrigation project. If water is required in large quantities for waste dilution there may be a possibility of otherwise treating or reducing the volume of waste.

Water versus Water

Following the same line of thought it is apparent that there are unconventional but possibly useful means of managing water that may replace the ordinary engineering solutions in meeting stated needs. We are accustomed to comparing tube wells with reservoirs as a source for irrigation water, or to comparing channel improvement with levees as a means of lowering flood stage. Some of the other possible choices are less obvious.

We may set at one side the possibility of increasing total water supply for an area by cloud seeding or by desalinization of mineralized water: while these may in time offer attractive solutions, for the immediate future seeding is to uncertain and demineralization is too expensive to be practicable in all but a few situations. Other demonstrated measures are at hand. Monomolecular films are beginning to provide a means of evaporation repression which compares favorable in cost with numerous storage projects. The techniques of groundwater recharge and aquifer management are greatly improved: here is where the great bulk of the water of the continents already is stored. Spray irrigation for short drought periods of humid croplands has shown itself capable in some situations of yielding very large marginal returns at low capital cost. Measures to cut the use of water lost in industrial processes can be substituted for schemes to transport additional supplies to meet rising industrial demands.

We are beginning to see that just as a unified system of multi-purpose storage dams can be superior to a hodge-podge of independent, single-purpose projects so a program of water or alternative administrative measures may be superior to the strictly engineering program. This is suggested in Table II. In presenting this I am not arguing that the day of the large multi-purpose dam is past. I am arguing that as we move toward more refined methods of water management, and as the patterns of water use become widely fixed in the man-made landscape, the major engineering structures will be seen increasingly as part of a complex of measures which give a flexibility that never could be achieved by use of engineering alone.

Table II

A Comparison of Conventional Water Management and Alternative Measures

Purpose	Conventional measure	Alternative water management	Alternative nonwater management
Increase crop production	Irrigation of arid land	Humid land irrigation	Fertilizer, seed, pesticide inputs
Stabilize livestock production	Irrigation for forage supply	Additional water points in grazing area	Forage shipment, livestock transport, and insurance
Reduce flood losses	Dams, levees, and channel improvement	Flood prevention	Land use regulation, structural adjustments, and emergency evacuation
Provide water for growing urban area	Surface storage, wells	Evaporation repression, ground-water recharge	Water rates, regulation of use

Complementary Activity

The history of arid land irrigation in many sectors of the earth during the past sixty years teaches us with a record of poignant disappointments the weight of the next problem. It is the question of what complementary activities are essential to assure the expected flow of benefits from a water management project. The expansion of irrigation has demonstrated persuasively that if the anticipated benefits are to be obtained much more must be done than to supply water to the fields. Provision must be made for distribution ditches, drainage facilities, means of curbing overapplication and under-application of water, credit facilities, crop transport and marketing, new seeds and fertilizers, educational services, and a goodly number of other services. Time and time again projects have been put forward and constructed without adequate provision for one or more of these points, and partial failure has been the result. Sometimes a necessary complementary measure is overlooked as was the case with drainage in parts of the Indus Basin. More often, it is assumed that the need will be met by some other means. This is the convenient argument in Thailand where to furnish the complementary measures for a small irrigation project the close co-operation of seven different government agencies is expected but rarely realized.

Similar situations apply to other engineering programs. Unless flood control in a growing area is accompanied by land use regulation and information programs the flood losses may soon equal the total when the construction began, as illustrated in the Ohio and Damodar valleys. Meeting the rising water requirements of wasteful industrial users without regulating the usage by rates or otherwise may only encourage still greater waste. A highly efficient hydro-electric generating plant may need to be supplemented by fuel-electric capacity, transmission lines, promotional rates, and support for purchase of new consumer equipment if the power use is to be expanded as hoped.

The cost of complementary measures may equal or exceed the cost of the water management structures alone. It has been estimated in some irrigated areas that land settlement costs and the expense of necessary credit, marketing, transport, and educational facilities will exceed the investment in irrigation facilities. Where large blocks of cheap power are to be generated the investment in manufacturing plants to use the power may equal the generating station. In general, the lower the per capita income of the country the larger the proportion of investment for complementary activity, including social services, and the less the likelihood that this will be carried by private investment.

Fiscal Limits

The magnitude of complementary works reminds us of the obvious curb which fiscal condition places upon the size and timing of water development. In low income nations, even those enjoying generous external aid programs, these limits are acute. Our estimate of maximum capacity for the four Lower Mekong countries, for example, was that they could not be expected to invest more than 18 per cent of the gross national product and that no more than 8 per cent would be in the public sector. Perhaps one fifth of the public investment might be expected to go into water management. But of that amount 40 to 50 per cent may be required for complementary works. By this process of estimation a rough approximation of capital expenditure opportunities on an annual basis may be reached.

The timing of such investment needs to be set in relation not only to prospective revenue but with regard to the probable time streams of benefits from projects, their effects upon foreign exchange, and their use of underemployed labor. Oftentimes, as recent analysis in India has suggested, these considerations tend to favor smaller projects which pay off earlier, make smaller demands upon foreign currency, and use larger amounts of local labor than do the larger undertakings. Dispersed supplementary irrigation for already cultivated lands may be preferred over new irrigation with its attendant heavy requirements for land settlement. Smaller fuel-electric plants may be given priority over cheaper hydro-electric plants requiring larger blocks of capital and longer periods for construction, as in Malaya or Turkey.

Sometimes it is argued casually that external aid is not subject to these limitations. It is forgotten that even cash grants might be available for alternative projects, that they require local currency, and that they cannot be certain to continue as long as many large-scale water programs.

Institutional Adjustments

Attention already has been called to the need in some aspects of water development to link institutional changes with engineering works in order to assure project results. This is not likely to happen unless the administrative organization and its legal foundations are sufficiently broad to permit persistent attention to not only those aspects of the program but the continuing relation of water activities to national economic and social efforts. Clearly the best design system of engineering works can fail if not administrated by an agency with competency and sufficient authority. It is less clearly recognized that successful engineering design must be shaped with an eye to the administratively practicable. There is little point in building canals where there is no prospect that credit and extension services will promote the desired shift in cropping systems. A reciprocal adjustment between engineering and institutional arrangements is required.

One attractive answer to this problem is to propose or soon establish a comprehensive regional development authority to handle all related economic and social problems. The Tennessee Valley Authority is the prototype and the Khuzistan development program is its most recent expression. The results of regional authority efforts are impressive and yet they commonly fail to reproduce themselves.

Among the reasons are the difficulties of reconciling regional aims with national policies and the opposition of national agencies and administrators to special treatment of one area of the country. What-ever the reasons, this form of solution is unlikely to be widely replicated, and more cumbersome machinery is in store.

Complications are especially acute where water moves across international or interstate borders. Much generality has been written about international stream management, and little is known about concrete lessons from it. Possibly one lesson is that the earlier the member nations or states join in impartial schemes for collection of basic data the better the prospects for later agreement. Another is that negotiation of detailed water allocations and administrative machinery can better follow than precede the drafting of tentative basin plans. National rivalries and regional claims are less likely to bulk large when positive schemes for using the available water are on the table; then, administrative machinery can be designed to help carry them out.

Physical designers thus are caught between two sets of administrative considerations in water planning. On one hand they must try to anticipate institutional changes which should accompany engineering work. On the other hand they must seek judgment as to how far these changes may be expected to go, and attempt to cut the cloth of new projects accordingly.

Summary Questions

All of this may seem painfully elementary. It is elementary in the sense that it deals with basic views and assumptions upon which elaborate designs — and monumental projects — are built. If there are lingering doubts about the wisdom of water investment programs it is because in no small measure the problems associated with them have been treated casually or obtusely. One way of gauging the extent to which they have received balanced consideration is to put the following questions to any water development proposal that emerges:

1. Are the aims and design criteria stated explicitly?
2. Does it canvass possible non-water measures to reach these goals?
3. Does it consider alternatives to the conventional engineering measures?
4. Are complementary measures included?
5. Are fiscal limits recognized?
6. Does it specify needed institutional changes?

High income nations can afford to satisfy their yearning for dramatic concrete monuments or for distribution of public largess among remote regions by investing heavily in water development programs that ignore some of these questions. They can pass lightly over the economics of these investments and later can set about remedying unexpected waves of damage which are set in motion. Low-income nations — the ones which typically must relate their new water projects to development aid plans — can ill afford to do so. Their financial and personnel resources are so limited that they must seek more persistently and imaginatively for solutions that maximize the net social returns.

References

1. E. C. A. F. E.: Multiple-purpose river basin development, Part I, Manual of river basin planning. United Nations, 1955.
2. *Epstein*, T. S.: Economic development and social change in South India. Manchester University Press, 1962.
3. *Farmer*, B. H.: Pioneer colonization in Ceylon, a study in Asian agrarian problems. Oxford University Press, 1957.
4. Food and Agriculture Organisation: Forest influences, 1962.
5. *Gadgil*, D. G.: Economic effects of irrigation. Report of a Survey of the Direct and Indirect Benefits of the Godavari and Pravara Canals. Gokhale Institute of Politics and Economics, Poona, 1948.
6. *Krutilla*, J. V., and Otto *Eckstein*: Multiple purpose river development: Studies in applied economic analysis. John Hopkins Press, 1958.
7. *Maass*, A. and Maynard *Hufschmidt* and others: Design of water resource systems. Harvard University Press, 1962.
8. United Nations: Report of the Conference Secretary-General on Integrated river basin development in less developed areas. United Nations Conference on Science and Technology, 1963.
9. United Nations: Integrated river basin development: Report by a panel of experts, 1958.
10. *Weber*, Eugene W., and Maynard *Hufschmidt:* River basin planning in the United States. United Nations Conference on the Application of Science and Technology for the Benefit of Less Developed Areas, 1963.
11. *White*, Gilbert F.: Strategic aspects of urban flood plain occupance. Proc. A. S. C. E., Hydraulic Division, 1960, 89—102.

II. Community Water Supply in the Developing Countries

by H. G. Baity

Part I

Depatures from Normal Design Standards

To the sanitary engineers of Europe and North America it is near sacrilege to suggest any relaxation in the standards for water supply and treatment works which have been evolved during the past half-century. As the result of research and experience we have developed plants and processes that are marvelous in their physical aspects and miraculous in the convenience, comfort and safety that they afford to our people. As these advancements have been achieved, and experience interchanged, there has come about in the Western World a high degree of standardization in water works practice. Except for refinements and embellishments, a water system or purification plant in one part of this area reflects essentially the same basic standards and features of design as those of the installations in any other part. These standards have been found through the years to produce dependability, safety and long-term economy in this vital service of water supply. We like to believe that we have reached a level close to perfection. It is not surprising that in the eyes of designing engineers and public health officials these standards have become sacrosanct. There is no quicker way to raise their hackles than to suggest a modification of them.

In this modern age of gadgets, labor saving devices, competitive industry and automation there has come to the water works field its share of refinement of equipment and embellishments which may not be functionally necessary but which we incorporate into our designs for the sake of achieving the n^{th} degree of efficiency, convenience or beauty — or to match the exotic works in the neighboring city or those of a competing engineer. In situations where labour is scarce or expensive automatic devices may be justified, but more often the motivation comes from the pride of the designer. The clever salesmanship of equipment suppliers if often an even more potent influence. Some plants look like a catalogue of these companies.

In addition to these influences, civic pride often plays an important part in extravagance of design. City councils love their towns, and they like to leave monuments in them which will both tickle the civic consciousness and perpetuate the memory of the city fathers. Water purification plants sometimes look like cathedrals and elevated tanks like campaniles. This civic urge is not restricted to the developed countries which have money, but is often found to be even stronger in the underdeveloped countries having great pride and aspirations to recognition.

There are some potent arguments in favour of high standards and aesthetics — even monumental extravagance — for water supply works where the costs can be afforded. In addition to the practical matters of dependability, safety, convenience and long-term economy in the furnishing of this precious commodity, there are the important matters of civic pride and the effects upon the morale and efficiency of operational and managerial personnel to be taken into consideration. It may also be argued that beautiful and well-equipped plants contribute importantly, through better maintenance and operation, to the quality of the finished product. So, no loud complaint can be raised against the spending of money for high standards, refinements and embellishments provided the financing of these things can be done locally and without difficulty.

A Different Background

But in the developing countries, the picture is quite different. There the need is great for even the elemental things. Public water supply is often almost non-existent. Financial resources are extremely limited, and these improvements must generally be made by financing from outside the country — often in the form of grants from other governments. As contrasted with conditions in the countries which are providing the assistance, there is usually a bountiful local supply of unskilled labour, but a dearth of skilled or even semi-skilled workers. Usually there are no engineers available for service, or even for training, in the specialized duties involved in water works operation, maintenance and management. The climate is usually tropical, and never at freezing level, which should have an obvious and enormous effect upon the housing of plants and the protection of hydraulic facilities. There are many other conditions, too numerous to mention here, which suggest not only the justification, but the demand for departure from certain of the norms and standards of the West in water supply design. One very great and variable factor is the quality of raw water encountered in tropical areas.

In addition to these influences upon design, there is the more important consideration of the people to be served. Very few of them now are provided with water through pipes, and often it must be carried for long distances by the women. The task of supplying safe and adequate water to a majority of the people is an enormous one and will take a long time. In view of this situation it becomes logical to employ the limited funds that become available *to give water to as many of the people as possible rather than to give a perfect supply to a few*. Under this doctrine we dare to suggest some modifications to the holy standards of the West. We can already hear rumblings of protest.

Governing Principles

The suggestions for modifications of standards and for the short-cuts which follow are conditioned upon the following principles:

1. That a supply of good water is essential to any marked improvement in the standard of living of a people.
2. That water supplies, once provided, must be maintained, be safely operated, be continuously available and be augmented to meet community growth.
3. That a master plan shall be prepared showing definite stages of development, and that each element of work or expenditure must fit into this plan. No work should have to be scrapped.
4. That water supplies should be on a self-sustaining basis. They should neither be profit-making nor require subsidy.
5. That supplies should be planned for stage development, so that revenues can meet operational costs and the periodic capital outlays for stage construction.
6. That departures from normal design standards must not be carried to the point of threatening the sanitary safety of the water supplied to consumers.
7. That necessary economy in initial construction is often controlling, and may not result in long-term economy.

Economies in Design Standards

We offer below, in succinct outline form, some suggestions for departure from normal standards which may result in appreciable economies in water supply work in the developing countries:

General Considerations

1. Stage Principle of Construction
   a) Use short stage of, say, 10 years.
   b) Must fit into master plan.
   c) Should not result in scrapping of any previous construction.
   d) Incremental extensions should be made without excessive cost.
   e) Provide only facilities needed within the stage period, not 20 or 30 years hence.
2. Incremental Water Service
   a) Service first of most densely populated areas.
   b) Extensions later to sparsely settled areas.
3. Per Capita Water Demand
   a) First stage development may involve primarily hydrant distribution, with demand of about 40 litres/cap./day.
   b) Later stages with more house connections and greater over-all average consumption, say 100 litres/cap./day.
   c) Final stage with higher living standards, say 200 to 250 litres/cap./day.
4. Engineering and Labour Services
   a) Competent engineering services absolutely necessary.
   b) Skilled labor highly desirable and economical, but rarely available.
   c) Semi-skilled labor may be developed, is locally available, but uneconomical.
   d) Unskilled labor in bountiful supply can work well under supervision.
5. Grouping of Water Supplies for Economy of Operation, Maintenance and Management.
   a) Several small supplies under the administration of personnel at the large one.
   b) Several small supplies supervised by "circuit-riding" specialists of governmental agency.
   c) Stores, laboratories and accounts to be kept at a central location.
   d) Water rates in entire area should be uniform.
6. Standardization of Equipment.
   a) Capital costs of stocking spares greatly reduced.
      (i) Pumps, engines, pipes, valves, meters, etc.

b) Permits interchangeability where various plants or supplies are under joint supervision or management.

c) Might ultimately reduce competition in purchasing.

(i) To avoid this, standardize on two competitive makes.

Water Supply Facilities

1. Intake Structures.

a) Intake diversion dam may suffice in first stage.

(i) Possibility of restriction of supply during periods of extreme drought.

b) Impounding reservoir to be provided in later stages.

2. Gravity Supply Lines.

a) Formerly used cast-iron pipe sustaining pressures of 10 atmospheres, or more.

b) Can now design for pressures of 2 to 3 atmospheres using cement-asbestos pipe.

c) May lay long lines on stage principle.

(i) First stage employs one line.

(ii) Second stage a larger parallel line for $^1/_3$ distance connecting into first line.

(iii) Third and fourth stages, completion of parallel line, connecting with first at third points.

d) Velocity of flow may be increased to several times normal if precautions taken against water hammer.

e) Chambers for pressure interruption may be omitted if velocity exceeds 2.5 metres/sec. and if no valves exist on line except at upper end.

(i) For first or later fillings provide air vents at high points on line.

f) Where supply lines are equipped with valves, savings can be made on lines larger than 30 cm. by use of valves of smaller size.

g) For further economy, lines for raw water supply (water to be treated) can be made of vibrated plain concrete.

(i) Laid on hydraulic gradient.

(ii) To obtain maximum flow and to produce slight outward pressure, use weir to produce head of about 1 metre and full wetted perimeter.

3. Pumping Stations.
   a) Flexibility provided by multiple small units.
   b) Cost of stand-by capacity reduced by use of small units.
      (i) For example, install 3 pumps of 50% of maximum duty (providing 1 stand-by) or 4 pumps of $33^1/_3$% of duty (providing 1 stand-by).
   c) Pumps should not be sized for duty beyond their expected life.

Water Treatment Plants

1. General Observations.
   a) Primary attention to be given to basic utility of structures and equipment.
      (i) Many costly features provided to look nice or scientific.
      (ii) Assistance of suppliers is valuable, but their supersalesmanship to be resisted.
      (iii) Some unnecessary features result from emulation of other designs, some from inertia of designers.
   b) Climatic conditions an important factor.
   c) Shortage of scientific personnel and skilled labour dictates simplicity and fool-proofness of treatment works.
   d) Abundance of unskilled labour dictates minimum use of automatic or labour-saving devices.
      (i) E. g. manually-operated valves should be employed.
2. Housing of Treatment Plant.
   a) Building structures may be minimal.
      (i) Not needed over basins or even filters.
      (ii) Required only over chemical storage, chemical feed equipment, chlorinators, laboratories and pumping equipment.
3. Chemical Feed Equipment.
   a) Solution-type facilities cheaper to install, but difficult and unreliable in operation.
   b) Dry-feeders probably justify their increased cost.
      (i) For example, install 3 pumps of 50% of maximum duty available.
4. Mixing Facilities.
   a) Mechanical flash mixers and mechanical stirrers desirable, but very expensive.

b) Gravity mixing chambers with variable baffle spacing to provide decreasing velocity for flocculation are satisfactory, cheap and practical.

c) Adequate mixing and flocculation cannot be comprised.

5. Coagulation Basins and Precipitators.

a) Basins with horizontal flow, and with good influent and effluent devices can have retention period reduced to 2 hours, provided effective 15 to 30 minute mixing precedes.

b) In vertical-flow precipitators the normal detention periods may be reduced by the following amounts if the applied water is well flocculated:

(i) With alum	15 per cent
(ii) With iron salts	25 per cent
(iii) Softening treatment	25 to 35 per cent

6. Filtration Plants.

a) Type of filter: Because of its "Package" nature and supposed ease of operation there has been a tendency to install pressure filters in the under-developed countries. This seems to have been a great mistake. Operators, at best incompetent, cannot see what is taking place in the filters and have no indication when to clean or repair them. They are soon failing to perform their function. Open gravity-type filters are much preferable for use under these conditions.

b) Filter sand of effective size 0.60 to 0.65 and uniformity coefficient below 1.60 may generally be used.

c) Retain standard gravel sizes and depths.

d) Underdrain system may be of simple and durable perforated pipes or false bottoms, rather than elaborate or corrosible patented devices.

e) Rate of filtration can be increased to 175 metres/day for coagulated water and 225 metres/day for iron removal.

f) Backwashing rate of 0.75 to 0.80 metres/min. for water at 15° C.

g) Decorative operating tables can be omitted.

h) Slow-start controls on filters can be omitted.

i) Complicated rate-controllers on filter units can be substituted by orifices in effluent lines and simple graduated differential manometer, with manual valve control of flow.

j) Complicated and expensive loss-of-head guages can be replaced by simple manometers with scales alongside.

k) Hydraulically or electrically-operated valves can be replaced in design by simple hand-operated valves.

l) Most of the automatic recording guages can be dispensed with.

(i) A main meter on the plant influent line, with its indicating and recording features, should be retained.

m) Reliable chlorinators employing chlorine gas should usually be provided.

7. Clear Water Reservoir Capacity.

a) Size depends largely upon dependability of water source, pumping equipment, fire protection codes and insurance rates.

The following are rough suggestions:

(i)	With one long supply line	24 hours
(ii)	With two long supply lines	12 hours
(iii)	With nearby pumped source	6 hours
(iv)	Equalizing tanks in area served	6 hours

b) If source of supply dependable and fire protection not involved, capacity need be only sufficient to equalize hourly variations in rate of consumption.

Distribution Systems

1. Pumping Stations.

a) Suggestions made previously regarding raw water pumping stations apply with even more force to service pumping stations.

(i) Small units with a high degree of flexibility desirable to cope with variations in water demand.

(ii) Considerations of fire protection may be an important or governing factor in providing pumping capacity.

2. Trunk Mains.

a) Cannot usually effect economies by modifying quality or classification of pipe used.

(i) Cost of pipe usually less than 40 % of total cost of line.

b) With long lines same types of economies as those previously described for gravity supply lines can be achieved, under stage system of construction.

c) Pressure mains may be designed for velocities (and head losses) which are exceeded 20 per cent of the time.

(i) Pumps would thus be working 20 % of time at a slightly less efficient point on their characteristic curve.

3. Booster Pumping Stations.
   a) May be economically used for increasing capacity of undersized trunk mains.
   b) May be necessary for topographical reasons to equalize pressures in distribution systems.
4. Elevated Storage.
   a) Can be reduced to 50 per cent of average daily consumption for gravity supplies.
   b) Can be reduced to 30 per cent of average daily consumption for pumped supplies, provided pumping station has reserve capacity of 30 to 35 per cent of average daily consumption.
   c) Above values may require modification by considerations of fire protection.
5. Distribution Systems.
   a) Careful design and choice of materials can effect notable economies.
   b) Distribution piping should not be scrapped or relaid.
   c) System to be designed so that subsequent mains laid under stage system may strengthen and restore working pressures.
   d) New and cheaper piping materials may often be used economically.
      (i) Asbestos-cement pipe well-proven and non-corrosive, but must avoid excessive physical shock.
      (ii) Plastic pipe of many types now available in many sizes.
         (1) Must consider possible effects of heat, rodents and insects.
         (2) Must be sure non-toxic materials are used.
   e) Shut-off valves may be reduced so as to put three or four street lines out of service instead of one.
   f) Hydrant spacing may be increased to 80 to 100 metres, if fire protection regulations permit.
   g) Hydrant outlets need not exceed 80 mm. in diameter.

Other Economies

1. Partial Treatment of Water.
   a) Where hygienic quality of water supply permits, may use partial treatment in first-stage development.
      (i) Sedimentation and chlorination.

(ii) Natural filtration, by using river-bed or impounded sand as strainer.

(iii) Procedures must fit into stage plan.

(iv) Water must be safe for human consumption.

Postlude

If many, or most, of the suggestions contained in this paper were followed, our illustrious sanitary mentors would doubtless turn over in their graves, and we ourselves might be shunned by colleagues upon return to our home country.

It is not suggested that all of these short-cuts and deviations be employed in any given case. Some, even several, of them may be applied without undue hazard where money is scarce and where the need to alleviate thirst is great. Everybody will be happy with the result, and especially the increased numbers of common people who may at last have water that is adequate and safe for their needs.

It has been proven in the doing that under the pressure of necessity the costs of water supply and treatment works, by careful design, and by cutting corners on convenience, aesthetics, civic pride and luxury, can be reduced to approximately one-half of those required under normal Western criteria of design.

Health agencies are understandably the most vocal of all in insisting upon high waterworks design standards that have a bearing upon the hygienic quality of the finished product. They would stubbornly resist the relaxation of standards that implied any threat to water safety. In fact, health people are often accused of being quite arbitrary about such matters. However, in the light of sanitary and economic conditions as they exist in the world of today, it is believed that they would prefer water systems with modified standards serving the maximum number of people rather than a few ideal facilities or long delays in providing relief for existing conditions.

This presentation has been related to surface-water supplies and treatment works of considerable size, serving towns and cities, rather than rural villages and individual homes. It is in these larger installations that one might find and justify differences in design standards as between the wealthy developed and the impoverished underdeveloped countries.

In the case of ground-water supplies there are few economies to be effected in the development of wells, and the other features of such systems are similar to those of surface supplies.

On the smaller installations there is not so much room for variance of standards, if reasonably sanitary conditions are to be maintained.

The list of references which follows contains some excellent publications on small-scale water supply, excrete-disposal and sewage-disposal facilities. Other useful reference materials are available from the health and public works agencies in many countries.

References

1. American Society of Civil Engineers: Water Treatment Plant Design, Manuel 19. American Society of Civil Engineers, New York, 1940.
2. *Wagner*, E. G. & *Lanoix*, J. N.: Excreta Disposal for Rural Areas and Small Communities. Monograph Series No. 39, World Health Organization, Geneva, 1958.
3. *Wagner*, E. G. & *Lanoix*, J. N.: Water Supply for Rural Areas and Small Communities. Monograph Series No. 42. World Health Organization, Geneva, 1959.
4. American Society of Civil Engineers: Sewage Treatment Plant Design, Manual 36. American Society of Civil Engineers, New York, 1959.
5. *Cox*, Charles R.: Guides to the Design of Water Treatment Plants. Agency for International Development, Washington, 1960.
6. *Zlokas*, Dusan: Considerations Involved in Establishing Minimum Design Criteria. Report of the Mediterranean Seminar on Community Water Supply. World Health Organization, Geneva, 1960.
7. *McClure*, A. L.: Economic Considerations in the Programming, Design and Operation of New Water Works. Report of the Africa-Eastern Mediterranean Seminar on Community Water Supply. World Health Organization, Geneva, 1961.
8. *Buck*, *Seifert* and *Jost:* Standard Water Filtration Plants for Small Communities. Puerto Rico Aqueduct and Sewer Authority, San Juan.
9. *Guzman*, Ramon M.: Standardized Plant Design: Pro and Con for Puerto Rico. Water Works Engineering, New York, August 1962.
10. U. S. Department of Health, Education and Welfare. Public Health Service. Manual of Individual Water Supply Systems. U. S. Public Health Service Publication No. 24, Wishington, 1962.
11. World Health Organization: International Standards for Driving Water, Revision No. 1. World Health Organization, Geneva, 1963.

Part II

Water, People, and Progress

Since the dawn of history there has been a close association between man and water. This is with good reason, considering man's dependence upon water, not only for his own life but for the life of his animals, for his food and for all the other things that support his existence. The great civilizations of the past have been nurtured by the water-courses along which they nestled — the Tigris, the Euphrates, the Nile, the Indus, the Brahmaputra, the Rhine, and many others. The development of these cultures — and all others since the race began — have depended upon the presence and use of water. By contrast one finds only the shells of great cities where the availability of water supply was an after-thought, standing there in all their magnificence as silent reminders to us in this age of the penalties of forgetfulness, negligence or prodigality.

For those of us who have spent our life in the well-watered parts of Europe and America, blessed by rainfall and stream-flow that are both bountiful and equable, it is difficult to appreciate the full meaning of the value of water in other parts of the world. In most of these areas, including most of Africa, Asia and Australia, and parts of other continents as well, water is a precious commodity and the gaining of it is usually a difficult undertaking. To add to the natural difficulties, man has by his continued and wanton despoliation of vegetative cover through the centuries transformed into desert vast areas that once yielded water to support life. Taken as a whole, this planet is a very thirsty place, and it promises to become more so.

In a recent address before the United Nations Conference on the Application of Science and Technology for the Benefit of Less Developed Areas the Director-General of the World Health Organization has portrayed eloquently the disease situation in the world, and has pointed out some important causations. Although precise statistics are not available, Dr. Candau estimates that 70 per cent of the world's population of 3,000 million is without a supply of drinking water that is either adequate or safe, and that 85 per cent dispose of their excrement in a most primitive and dangerous manner. These are serious thoughts in terms of their public health implications. The ways by which people get their water is a story of slavery and tragedy, unbelievable to the people of the West who have always drawn it from a faucet. At some places it may be plentiful in quantity as it is dipped from rivers, canals, klongs or water-holes, but its quality is foul and lethal. In other places the leading commercial enterprise of the town may be the purveying of the precious dirty fluid, called water, from carts, donkey-borne casks, gasoline-tins or goat-skin bags at prices 10 to 50 times the cost of clean water from the faucets of piped supplies. In still other areas, where rainfall occurs only sparsely or seasonally, the water to sustain life has to be carried on the heads or shoulders of people — often for many, many miles. This is the customary system of supply over much of the world, and it is a task which has traditionally fallen to women. It is not uncommon to find the women of the household using from one-half to all their long working hours in this back-breaking, foot-bruising labour. In some places polygamy is justified on the basis that one woman is not enough to provide ample water for the needs of the lord and master.

A recent survey in Latin America involving 182 million people shows that 39 per cent of all the people living in places of more than 2,000 inhabitants are without water service, while 70 per cent of those in smaller places are deprived of safe water. It was shocking to find one city of 160,000 in this area without any piped water supply, but this would not be considered unusual in some other countries.

A very revealing study of water supply was made last year in 10 countries of WHO's Eastern Mediterranean Region having a total population of 186,881,000. In the most populous country of this area only 1.0 per cent of the people were found to enjoy water under pressure from piped systems. In another of the more populous countries, and one which is considered among the more progressive, 44.5 per cent of the people were reported to have clean water furnished to their premises. These are the two extremes; the mean lies somewhere between, likely in the neighbourhood of the 4.8 and 12.0 per cent figures reported by two other heavily-populated countries.

The situation revealed by such statistics is depressing, but it becomes more so when we look toward the future and take account of the effects of population growth, urbanization, industrialization and the diminution and pollution of available water resources.

In the Eastern Mediterranean Region cited above there is under way in most countries a very active and encouraging programme of water supply development. For example, one country reports 42 municipal supplies now under way; another 159 new installations since 1955 which serve 3,145,000 people; while another having 68.5 of its population classified as rural serves almost half of them with clean water under pressure However, these laudable accomplishments lose some lustre when viewed in the perspective of population growth. In the country of the Region with the best record of water supply development over the past three years the percentage of people served by water increased by 4.5 per cent, while the population increase for the same period was 8.0 per cent. In the most populous country of the Region the population increased by 3.5 per cent during this 3-year period, while the increase in people supplied by clean piped water was only 0.1 per cent for the same time. What can be the ultimate consequence of population growths at 35 times the rate at which even these increments can be provided with clean water to drink? This is the tragic situation and the pressing question in a great part of the world today.

Added to the population effect are those bearing upon the yield and quality of water sources. The great waves of urbanization and industrialization now taking place threaten the meagre sources of public water supply that are still available unless timely and drastic precautions are taken to protect them from pollution. These problems call for foresight, statesmanship and action.

Quest for the Better Life

In the world of today there is great ferment and activity. Tides of nationalism are running high. Many influences are at work in many places and in many directions. Some of these are at cross purposes, but upon two objectives there is universal agreement: independence and better living. There is a widespread conviction that the pathway to higher economic levels is by the industrial route. The benefits of industrialization are believed to be almost magical, and it has become the touchstone of progress. In most of the under-developed countries all available funds are going as directly as possible into the building of industry. The planners are having a hey-day drawing patterns for the ordered economic and social development. They usually have a wealth and variety of assistance from advisers and "dog-gooders", some of whom may be serving gratuitously and without complete harmony of advice. This urge to industrialize is good within proper limits. The difficulty comes only when the planners and purse-string-holders overlook the matter of building solid foundations for their industrial structure. In their zeal for development they sometimes start building from the top downwards.

It should require no debate anywhere to establish the fact that good health is the necessary foundation of a sound economy. The planners must realize that the industrial development which they envisage must have both healthy workers and a healthy clientele. The first requisite of good health is good and safe water in adequate amounts for all domestic purposes.

The Greatest Needs

The great question is how this help can best be given. So great is the task of building or rehabilitating the needed water supplies of the world that it goes without saying that no nation, group of countries, nor all of the interested international organizations working in concert, could undertake to do the actual construction themselves. It is so vast that it would require billions of dollars, and much patient, persevering work spread over decades, to accomplish. Nor would it be a good thing for either the assisting or the assisted nations to have the problems solved by gift and largesse, even if it could be afforded. "Hand-outs" are not well appreciated or conserved. It is much better all around if the countries bear the major portion of this burden. And, in justice to them, it must be said that most of them are not seeking charity in this respect. It would offend some of them to suggest it. Many developing countries are able to gather rather impressive resources for the purpose, and many of them are carrying out programmes in this field that are creditable. They are sometimes lacking in suitability or efficiency, and always in ample size.

It would naturally be assumed that with everybody wanting and needing water, and with almost everybody willing to help provide it, the task of promoting, designing, building, operating and managing water supplies would be a delightful one. It is not so. There are many difficulties and pitfalls, some of a very unexpected nature. A few of the more usual kinds of problems are listed in the briefest possible form below:

1. The non-existence of proper water authorities; conflicts between multiple agencies having divided authority and working under conflicting policies; or jealousies and antagonisms between the various jurisdictions.
2. The disposition of some governments to consider water a Godgiven and free commodity, thereby excluding normal self-liquidation financing.
3. The problem of "free water", and the lack of adequate rate structures to support amortization of loans and the adequate operation and maintenance of works.
4. Unwarranted restrictions and limitations upon external borrowing for water supply development.
5. Intense competition for finances, and the diversion to other purposes of revenues legitimately belonging to the water supply agency.
6. Serious shortages of personnel in all departments of the water supply organization, involving vital functions such as long-term planning, design, the appraisal of the design of others, construction, operation, maintenance and management.
7. The lack of standard designs, especially for small installations, or suitable designs to cope with special conditions or to meet re-

alistically the problems of restricted financial resources and untrained operating personnel.

8. The non-availability within the country of necessary construction materials and equipment, and the lack of foreign exchange for its importation.

The most Effective Help

What an organization such as this Foundation could best do in this field is difficult to say. Perhaps it would be easier to point out things *not* to do. One type of thing *not* to do is to present developing countries with public works "on a silver platter" — works which have been designed, financed and constructed without their participation. It is the natural instinct of donors to do just that. The gift may be good, needed and useful, but the generosity of the giver — and even his identity — will soon be forgotten. It will probably not stimulate similar works, and its serviceability will be no more than "a drop in the bucket" compared with the need. But more important than all these considerations is the fact that no nationals have been inspired or trained to carry forward the programme into the long future.

The fulfilment of such a purpose is the heart and soul of any foreign aid programme. If nationals are not equipped to carry on desirable programmes the expenditure of money is futile. This should be the fundamental test. No nation or group of developed nations are able to rebuild the world. They can only set some good examples of how it should be done, and try to make sure that these examples will be regenerative. Regeneration is not possible without understanding and trained public servants. The main obstacle to growth in the developing countries today is the dearth of such people.

Most international agencies are agreed that their best investments have been in fellowships and training. Next to that come the undertakings in which the nationals have been closely associated with the planning, organization, designing and execution phases of projects. In the field under discussion here it is hard to conceive of a better use of resources than to bring hosts of promising young people to Germany for training in water supply practice. If donor governments should choose to carry out water supply projects in developing countries, this should be done on a cooperative basis, with local personnel sharing in all phases of the work. The resultant effect will be nuclei or corps of people with an understanding of the technical and procedural techniques that will enable them to project forward the long and tedious water supply programmes of their own countries.

Postscript

For reasons of convenience this paper has been written around the objectives and problems of community water supply. Of equal importance to the health and economy is the corollary matter of human wastes disposal. The two services go hand-in-hand, and both must be provided to get the full benefits of either. Most of the statements contained in this presentation about water supply relate with equal force to sewerage. By and large, the latter represents a deficiency of matching significance and even greater magnitude.

References

1. *Baity*, H. G.: Some Experiences of WHO in Environmental Sanitation. Proceedings of Sixth International Congresses on Tropical Medicine and Malaria, Lisbon, September 1958.
2. *Baity*, H. G.: WHO's Part in a Global Community Water Supply Programme. Paper presented before American Society of Civil Engineers, Washington D. C., October 1959.
3. *Logan*, John A.: The International Municipal Water Supply Programme: A Health and Economic Appraisal. Paper presented before American Society of Tropical Medicine and Hygiene, Indianapolis, Ind., USA, October 1959.
4. *Wolman*, Abel: Technical, Financial and Administrative Aspects of Water Supply in the Urban Environment in the Americas, Document CD 11/DT/1 (Eng.) Technical Discussions of the Directing Council, PAHO, Washington, 1959.
5. World Health Organization: Report of the Mediterranean Seminar on Community Water Supply, WHO, Geneva, 1960.
6. World Health Organization: Report of the Africa — Eastern Mediterranean Seminar on Community Water Supply, WHO, Geneva, 1961.
7. World Health Organization: Community Water Supplies: Report of Technical Discussions at 15th Session of Regional Committee for South-East Asia. WHO Regional Office for South-East Asia, New Delhi, 1962.
8. World Health Organization: Report of Group Meeting on Community Water Supply at Beirut. WHO Regional Office for Eastern Mediterranean, Alexandria, 1963.
9. *Candau*, M. G.: Address to United Nations Conference on the Application of Science and Technology for the Benefit of Less Developed Areas. Press Release WHO/11. World Health Organization, Geneva, 1963.

III. Flood Control and River Training in East Pakistan

by Khan Mohammed Azam

Introduction

East Pakistan is an agricultural country of 54,140 square miles, or 35 million acres of which 22 million are cultivable. The rapidly expanding population, presently estimated at 54 million, is expected to double in the next fourty years. The population density averages 1,000 persons per square mile, but some areas average 1,700 persons per square mile. Ninety per cent of the population are farmers, subsisting on low incomes and inadequate diet even in good crop years.

The future prosperity of East Pakistan depends on an intensified program of industrial development and the optimum development of the land and water resources. With improved farming techniques, irrigation, drainage and flood protection, the agricultural production can be increased to about four times the present level. Flood control and river training will be most important in the development of East Pakistan, because every year tremendous problems are created by the destructive floods which damage standing crops, valuable lands and property.

Rivers

East Pakistan is largely a deltaic plain formed by two of the world's greatest rivers, the Ganges and the Brahmaputra. These rivers are actively building both the flood plain areas and the delta's formation. The path of many old river channels that have been filled with silt deposits are now being farmed and some distributaries from the major rivers are rapidly filling, while others are only in the initial stages of development.

The Brahmaputra River originates in Tibet, flowing in an easterly direction for 700 miles, turning south through the mountains and flowing in a westerly direction for about 400 miles before crossing East Pakistan's northern boundary, whence it leaves the mountains and flows south across the deltaic plain as a wide braided river, joining the Ganges at Goalando near the central part of the Province. The maximum recorded flood of the Brahmaputra occurred in 1958 with a corresponding discharge of 2.5 million cfs.

The Ganges River originates in the Himalayan mountains and after flowing southward into India, flows in an easterly direction across India and into East Pakistan. This river has had a variation of less than 5 feet between its highest and lowest annual maximum water levels since gage records were initiated at Hardinge Bridge in 1910, when the highest stage recorded an estimated discharge of about 3 million cfs.

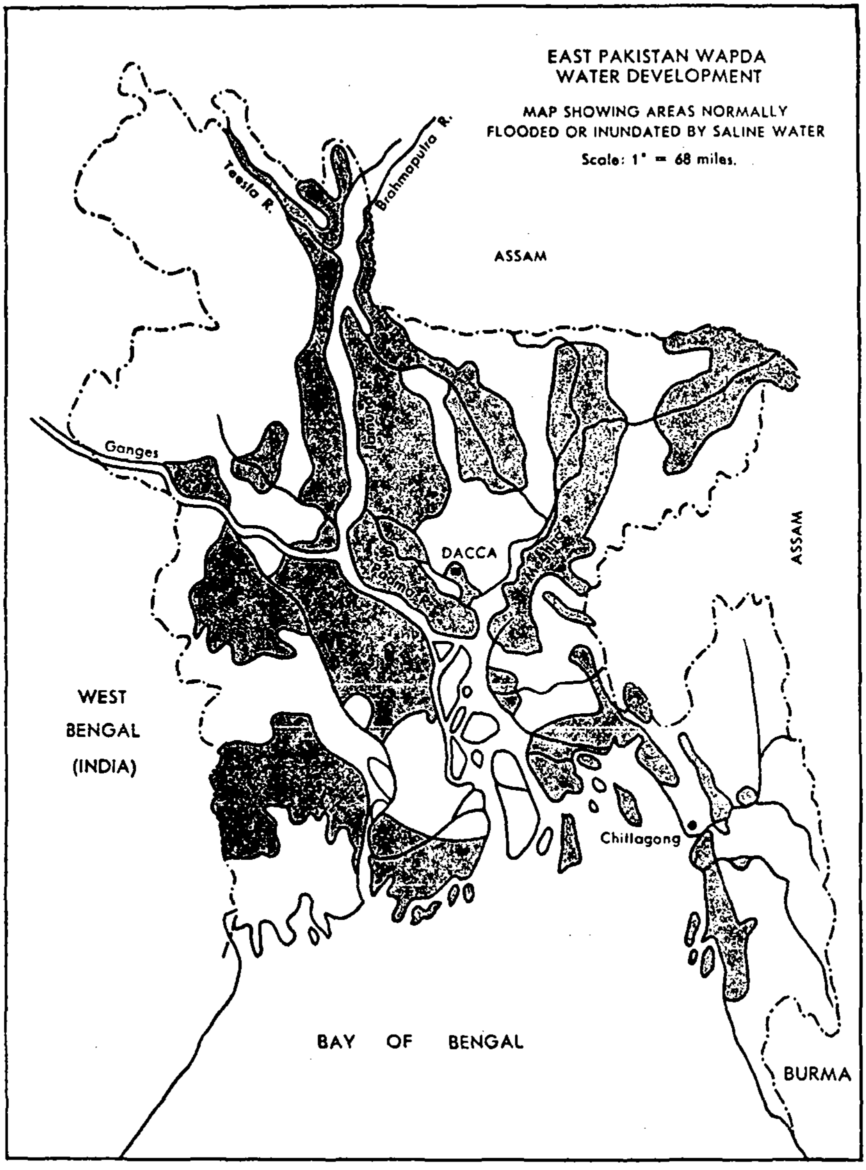
The Meghna is another major river, entering East Pakistan from Assam in the northeast and flowing southwest to its confluence with the combined Ganges and Brahmaputra immediately south of Dacca; and from this point, the one large river, called the Meghna, flows on to the Bay of Bengal. The length of the Meghna system is about 500 miles, half of which is in East Pakistan. The maximum recorded flood stage at Bhairab Bazar, northeast of Dacca, occurred in 1955 and the corresponding discharge was 456,000 cfs.

The Meghna usually peaks before either the Ganges or Brahmaputra, but is noted for its flashy tendency. The Brahmaputra and the Ganges do not usually peak at the same time, but this did occur in 1962 and caused abnormally high flood levels below their confluence at Goalando.

The immediate cause of floods is not the same in all parts of the Province, nor is the cause the same in many areas from year to year. Localized rainfall is an important cause of flooding in various portions of the Province and torrential downpours beginning in the months of April or May often cause extensive flooding in the northeastern regions. Considerable flooding occurs in the eastern areas bordering the Tripura hills where flashy run off is impeded in the flat flood plain. Flooding in the coastal regions is caused by extremely high tides The principal cause of the damaging floods which occur in areas bordering the major rivers is the depth and duration of overflow for several weeks of the monsoon season. Also, floods of particular severity result when these large rivers peak at approximately the same time, as was the case in 1954 and again in 1962. On the average, floods of such severity occur about every seven years, and catastrophic floods occur about three times a century.

Flood Control

Flood control is not a precise term, for it may mean one thing to an engineer and quite another to a layman. In East Pakistan a high degree of control, even if desired, is impractical to obtain due to: i) The re-



latively flat terrain of the deltaic areas of the Ganges and Brahmaputra which are available for engineering treatment; ii) Lack of suitable reservoir sites on these great rivers within East Pakistan wherein flood flows could be impounded to regulate the discharge; iii) Lack of practical means of diversion of a part of the flood flows from the main channel into side basins for temporary storage, or into natural distributary channels, or even into man-made channels.

The only applicable engineering treatments for the control or mitigation of flood flows in East Pakistan are: i) Channel improvements to retain within river banks some of the flow which now escapes; ii) Embankments to confine the overbank flows in areas needing protection; iii) Local protection projects to exclude flood waters and remove impounded drainage; iv) Major drainage projects to expedite run off and thereby reduce or even prevent overflow.

The problem of flood control along the major rivers will be approached as overflow regulation. Confining the river's flow by well placed embankments develops a more efficient channel. As an alluvial river develops into maturity it builds its own banks to heights which provide a degree of confinement of normal floods suiting its requirements. Man cannot wait for these natural processes to develop along alluvial rivers while he inhabits the bordering land, and from time immemorial he has helped himself (and the river) by building embankments. A great river such as the Ganges or Brahmaputra may not be forced (or shocked) into new ways without risk of failure, but it can be influenced by carefully planned works without undue danger.

In view of the short period of study and collection of data pertaining to the Ganges, and more especially to the Brahmaputra, it is prudent to approach the confinement of these rivers for the above purposes with due respect for their great energy, the growth and change of the delta, their stage and discharge characteristics, their unknown potential for flood flows beyond the limited period of record, sediment transport, and other characteristics which are relatively unknown at this stage of planning. Accordingly a step by step approach is indicated as the appropriate one. If agriculture can be given a degree of protection which will produce successful harvests 9 years in 10, 14 in 15, or possibly 24 in 25, the economy would be much improved. As the economy is strengthened a higher degree of protection could be considered in future years.

Flood Control Projects

A few typical on-going projects which provide flood control will be briefly described hereinafter to illustrate the wide variation in principles of protection, for each was specifically designed for a particular condition of flooding and suitability to the agricultural practices of the area protected.

The Brahmaputra Right Bank Flood Embankment Project provides an embankment along the right bank of the Brahmaputra River from Kaunia on the Teesta River to Sirajganj to protect about 594,000 acres low-lying from flooding. This project comprises a compacted embankment averaging about fifteen feet in height. A roadway constructed on the top will provide all-season transportation, and sluiceways constructed at the south of the distributaries from the Brahmaputra will allow water to enter the area as required. A similar embankment is being planned for the left bank of the Brahmaputra and when completed, the overflow almost up to Ganges will be controlled.

The Chandpur Irrigation Project area located along the eastbank of the Meghna River at Chandpur and divided into two parts by the Dakatia River, is flooded annually by the Meghna to a depth of 6 to 10 feet. The two separate areas will be encircled with flood embankments, thus forming two large polders of about 109,000 total net acres. A dual purpose pumping plant is provided to remove the excess rainfall during monsoon and to pump water for irrigation in the dry winter season. Two or more crops of rice, jute, sugarcane, lentils, etc., will replace the single crop of long-stem rice.

The Coastal Embankment Project estimated to cost $ 120 millions, is the largest and one of the most beneficial projects now under execution. The coastal area along the Bay of Bengal from the western international boundary to Cox's Bazar south of Chittagong is inundated during high tides by saline waters, damaging the land and standing crops. The coastal area is divided into small units by the webbing of interconnected distributaries of the Ganges, Meghna and other rivers. Each polder unit is protected from saline water by encircling it with an embankment. Pipe sluices with flap gates are placed in the embankments to drain the excess rainfall from the land during periods of low tide. When the tide is high, its flap gates close and prevent the saline water from entering the area. The increased crop yield will be provided to a net area of 2.4 million acres.

The Faridpur Drainage Scheme will provide improvements to lands which are low, annually flooded by the overflow of the Padma River and suffer from inadequate drainage. Silted distributaries are being dredged, straightened, and widened to make them more suitable to drain the area, thereby providing vastly increased yields to about 275,000 acres.

The East Pakistan Water and Power Development Authority

The East Pakistan Water and Power Development Authority was created to provide for the unified and coordinated development and utilization of the Water and Power Resources of East Pakistan.

Projects are proposed to the Provincial Government by *E. P. Wapda* on the basis of public need. Each project is scrutinized by the appropriate agencies of the Provincial and Central Governments. After the Central Development Working Party is satisfied on the financial feasibility, desirability of project, adequacy of domestic funds and either availability or excellent prospects of finding the foreign exchange, the project is sanctioned by the Economic Council of the Cabinet of the Central Government.

Upon sanction, the project is eligible for inclusion in the budget. The Central Government then allots funds to the Provincial Government and the Provincial Government in turn allots the funds to *E. P. Wapda*. The responsibility of finding local currency as well as foreign exchange is the responsibility of the Central Government.

E. P. Wapda then applies for the loan and provides all technical and supporting evidence to the lending agency required for justification. The loan is made to the Central Government; the Provincial Government concurs with the loan; and *E. P. Wapda* agrees on procedure and execution of the work.

E. P. Wapda plans the projects to prove feasibility to Provincial and Central Governments and lending agencies. *E. P. Wapda* maintains a large engineering staff and hires many consulting engineering firms. An American firm is currently being retained as general consultant to *E. P. Wapda* while special consulting firms include: German, Pakistani, American, English, Canadian, French and Swiss organizations.

After funds are made available, *E. P. Wapda* proceeds with design and construction of the projects. For Design, either Pakistani or foreign consultants are used or a combination of both. When the projects are small, *E. P. Wapda* Design Directorate does the design. Construction of major works and supply of permanent equipment are generally thrown open to international bids. Smaller projects will be built by Pakistani contractors with award of permanent material contracts after world-wide tenders to those successful bidders, whether Pakistani or foreign. The policy of *E. P. Wapda* on construction will be to adopt the course that gets things done. To accelerate execution of work, the *Wapda* established the Mechanical Equipment Organization whose main purpose is to make available to contractors a fleet of construction equipment with skilled people trained to operate and maintain them.

When the projects are completed, *E. P. Wapda* provides for operation and maintenance of the project and repayment of the capital invested in the project. Operation and maintenance are performed by transfer of personnel actually involved in the design and construction activities or by training the personnel on the job and abroad.

For repayment, the projects may be divided into: (i) Irrigation and drainage projects; (ii) Flood embankment; (iii) Navigation projects; (iv) Power projects. Actually any two and sometimes all four aspects are interrelated, and the act that fits the circumstances best from the point of view of collections is applied for the purpose. Within the framework of existing legislations it is possible to levy and collect from the beneficiaries of project constructions or users of electricity. The *E. P. Wapda* makes recommendations to the Provincial Government who in turn notifies the rates to be adopted. New legislation has been prepared and is now under the consideration of Government, whereunder it is proposed that for irrigation and drainage flat rates should be fixed to a ceiling limited by 10 % of gross annual increased benefits to the farmers, and the balance, if any, be a subsidy from Government, while the rates for power should be applied uniformly over the Province.

IV. Factors Influencing Planning and Operation of Irrigation and Drainage Projects in Developing Countries

by A. de Vajda

Among all types of water development schemes, irrigation and drainage projects require the most intensive permanent participation of large masses of the population. In any other type of water works, such as hydropower, navigation canals, reservoirs and pipelines for town water supplies, it is normally sufficient that a limited number of well-qualified technicians are charged with construction and operation of the works which can be executed by specialists, labour and equipment imported for this purpose. The operation of the works generally does not require much local personnel.

Irrigation and drainage works on the other hand cannot be maintained and operated, and in many cases, even not built, without the very intensive and permanent participation of the farmer and the cultivator. The preparation of the land, the maintenance of irrigation ditches, the right application of water, the correct choice of crops and rotations, drainage of the fields, needs permanent attention, as it is only by maintaining carefully the proper balance between soil, plants and water that good agricultural production can be maintained.

Although irrigation and drainage projects can be constructed by mechanical means, by large specialized organizations, if necessary without major participation of the local population, the actual handling of the water on the fields remains even in the most developed enterprises essentially in the hand of the cultivators.

It is therefore evident that the technical aspects of irrigation and drainage projects cannot be dissociated from social conditions nor from educational problems when discussing hydraulic land reclamation projects in under-developed countries. Nevertheless, for the sake of clarity it might be advantageous to divide discussions on particular requirements influencing planning, design and operation of irrigation and drainage schemes in developing countries, dealing first with technical particularities and then with other factors, although for above given reasons the difference in technical features of hydraulic land reclamation schemes in developing countries and highly industrialized ones is caused essentially by the difference in socio-economic conditions, to which we have to refer constantly during the discussions of technical questions.

The type of irrigation and drainage project is defined essentially by climate, soil crops and topography. For obvious climatic reasons irrigation developed originally in the arid tropics and subtropics, where it reached, in some cases, great perfection. The great civilizations in the arid and semi-arid tropics and subtropics, to mention only Egypt, Mesopotamia, Iran, Turan and the Indus valley — were based essentially on irrigation. Later and in an increased degree in our century, we are witnessing a strong expansion of irrigation farming beyond the classical areas of irrigated agriculture, an expansion which is not limited to arid and semi-arid parts of the world but which spreads into the temperate zone and the humid subtropics.

Today, supplementary irrigation plays a greater role than it did in the past and has penetrated in such countries as Southeast England and the Eastern United States.

In developing countries, simultaneously with irrigation farming in the old irrigated areas, we witness the same expansion into zones where until recently dry farming was predominant.

In West Africa, Ghana can be quoted as an example. Here — based on the Volta river, which is being harnessed for power production — sugarcane and rice irrigation is being introduced on a large scale. A similar trend can be observed in South Western Iran, where, apart from some rice growing in marshy areas, agriculture consisted essentially in dry farmed wheat and barley — today sugarcane, cotton and other crops are grown on irrigated land. Syria presents a similar picture.

In parts of the monsoon areas where rice cultivation was based to a very large extent on retention of rain water on levelled fields behind bunds, supplementary irrigation has become a major factor in ensuring and increasing yields.

This large increase in demand for irrigation water is creating problems in a great number of countries which were considered rich in water resources according to previous standards. The natural flow of the rivers is not sufficient, storage of flood water for irrigation is becoming an essential part of water development programs, requiring extensive engineering, geological, topographic and hydrological studies. Only in few of the developing countries engineers experienced in this type of survey and water planning are to be found, and in most cases technical assistance from abroad is needed.

Drainage, especially deep drainage, and covered drains (tile drainage) is another field where technical assistance can play a very useful role, especially in the case of drainage of irrigated land, where salinity problems are causing more and more serious troubles.

Technical assistance in these very important fields is needed for design and construction of major engineering structures, as well as for the design and construction of distribution and field irrigation systems and drainage works. In order to become effective, aid programs must give the greatest attention to the specific conditions of the countries to which assistance is being given.

The basic technical solutions of hydraulic land reclamation projects will in all cases be defined by prevailing climate and other physical conditions, and will therefore be very much the same in highly developed and developing countries. This applies essentially to major works, dams, diversion structures, main canals and major regulators.

But even here actual design details may differ from those used in highly industrialized countries, because of absence of skilled labour and because of the necessity to use local construction materials. The absence of timber, the high cost of steel, the difficulty of transporting over great distances heavy machinery to find skilled men to operate them, will influence design, often to a considerable degree. The large Indian dams are an example in which stone masonry has often provided economically more advantageous solutions than concrete. For the same reason, brick lining may replace concrete. It appears almost a contradiction, but in less developed countries the engineer's inventiveness is often put to a more difficult test than in highly developed industrial countries where all solutions as to materials and methods are easily obtainable and applicable.

In under-developed countries one can encounter two extremes — 1. the lack of labour in far away uninhabited parts which calls for certain solutions; and 2. the excess of labour, the employment of which is from the social and economic points of view an absolute necessity. In the first case mechanical methods may be applied, even if conditions for their use and for transport of actual equipment and for operation creates difficulties. In the second case construction methods have to be adapted to manual labour. The type of supervision required in both cases will create problems which are often difficult to solve.

The differences mentioned above exist to a greater extent in the construction of field systems and in the preparation of land. Not only because the methods of execution of this work might differ according to the need for using surplus labour or having to employ machines because of lack of labour, but also because the irrigation farming methods will be different once the project is put into operation.

The selection of types and layouts of the field irrigation systems, will be influenced among other things also by the stage of development in the countries in question.

Existing traditions have to be given due consideration. In countries of the Middle East and Central Asia, certain traditions of irrigation farming have evolved during the last hundreds or even thousands of years which should be changed only after studying the advantages and disadvantages of new solutions. It is true that in many countries where centuries ago irrigation was on a very high level, conditions have deteriorated and become much less efficient. Very often fields are badly levelled, too much water is used, causing uneven growth of crops and often wastage of water.

In many cases, however, the cultivator remained efficient and took great care in preparing his basins, his bunds, his field ditches and intakes, using methods which were suited to the soils, topography and crops. It is obvious that existing methods, which produce good results, should be encouraged and not unnecessarily changed to new methods because the irrigation engineer or agronomist is accustomed to other practices.

The skill of the cultivator should therefore play an essential role in the selection of technical solutions, together with the availability of repair and maintenance facilities and the existence or absence of well-organized irrigation communities. In general, institutional factors, including existing land tenure and ownership conditions will have a decisive influence on success of one or other solution.

Equally great is the role of the state of infrastructure on the selection of solutions, as absence of good communications, training facilities, will make the adoption of highly effective and expensive solutions difficult if not impossible, even if they might lead to a great increase in yields.

When deciding on technical as well as operational and economic features of irrigation and drainage projects in developing countries, we can learn much useful information by studying the difficulties encountered in large scale schemes experienced recently by Governments as well as the various aid programs. In the technical field the great weakness of many projects is that the works are not brought to their logical conclusion. One meets many cases where the irrigation distribution system is limited to major canals and structures and water is not brought to the farmer. Land levelling is in most cases also badly neglected. But the greatest technical weakness of irrigation schemes in almost all developing countries is the absence of adequate drainage.

On the "human" side the absence of a well-organized, well-paid and devoted irrigation service, and the lack of favourable land tenure conditions supported by farming communities organized between themselves and helped by public services are the greatest hindrance to success.

Lack of credit facilities and of a competent extension service completes this list of weaknesses which are inherent in many irrigation and drainage projects, but which are by no means limited to, but are more apparent in, developing countries than in highly industrialized countries which in their time had to go through some of the same troubles in their own developing phase.

Major mistakes continue to be committed even by able technicians, in some cases even by aid giving agencies by not giving due consideration to all factors, influencing the success of land reclamation projects.

New Schemes versus Improvement of Existing Systems

In many developing countries much more attention is given to new projects, than to improvement measures on existing schemes, although such improvement could yield much greater benefit, compared with the investment required, than new development requiring in most cases far greater capital layout not only for engineering works but also for land settlement, communications and related public services.

Large Schemes versus Smaller Schemes

In this relation we find almost everywhere a tendency to favour large schemes against projects of more modest dimensions.

It is certainly a sign of self-confidence and enterprise to see this desire for immediate large scale development. But it is not always realized how much preparation is needed for the reclamation of several hundred thousand hectares, what problems of manpower and organizational skill are involved, and how many years it takes until the new areas are absorbed and the invested capital begins to bring its fruits.

The advantage of starting first on smaller scale, gaining experience with a lesser risk of expensive mistakes, is not often recognized nor are the advantages in utilizing local initiative by initiating smaller or medium sized schemes and associating with them, from the very early stages, private groups and local administrations, given the attention they deserve.

The educational value of stepwise development for all concerned deserves far more consideration than it is actually receiving.

Technical Factors

It is difficult to decide which phases of irrigation and drainage development require more attention.

Planning of Irrigation and Drainage Works

The study of all factors needed for careful planning and design needs much more attention in developing countries than in countries where the basic services, such as meteorological, hydrological, geological, agronomic, soil and good topographic services exist. The greatest short-coming of many new projects in developing countries which lead to wastage of funds and economic ruin to the new settlers, was that the basic conditions were not studied sufficiently. In many instances large investments were made by Governments and by foreign financing authorities without proper investigations. The greatest contribution foreign aid can make to the development and improvement of irrigation farming is to provide the Government with the necessary basic data, such as good topographic maps, soils and land use maps, rainfall and hydrological data. It is equally important that agronomic trials should be carried out with irrigated crops for the suitability of which insufficient data exists.

Existing data should be carefully scrutinized before it is used for design purposes. From the hydraulic point of view the total available amount of water supplies should be studied carefully and this study should include information on existing water rights. Very often it is not known sufficiently how much water has been already allocated to existing users.

The best safeguard against poor water planning is to study entire watersheds or special watersheds, or in the case of groundwater, entire groundwater basins, establishing a balance which should also include the possibility of improvement of the regime by storage of water spreading.

Overpumping the groundwater is an evil which is making itself felt on a dangerously increasing scale in more and more countries.

These points are of course all commonplaces, but I consider it important to emphasize them because of the large number of projects which have been started and built without sufficient study.

One cannot emphasize sufficiently the importance of adequate soil investigations. It has been experienced in many countries that the danger of salinity and alkalinity is not taken seriously, especially where under conditions of dry farming no major salinity and alkalinity symptoms have become apparent. Conditions change substantially when the irrigation system is completed and proper drainage is not provided.

Selection of crops is often being made without proper preliminary study. Study of the markets for these crops from both short and long term point of view, as well as the agronomic possibilities should be given much more attention than is done in many cases.

The decision on the water requirements should not be left to the engineer, but the agronomist should be called in for consultation.

Wherever possible development should start with agronomic trials and small pilot farms. In areas where not, or only insufficient, experience exists in irrigation farming, it is always a great advantage to begin with irrigation farming with such trials and small pilot schemes. It is better to learn from mistakes made on a small scale than to embark immediately on large scale works where correction of unavoidable mistakes is not only difficult but also very expensive.

Irrigation Design

The source of water supply will depend on natural conditions. It might be surface water made available from reservoirs, lakes, rivers or springs by gravity flow or lift — it might be groundwater. The basic solution will be essentially the same in highly developed and developing countries.

As regards the selection of the type of irrigation — gravity irrigation (flooding, furrow or border) or sprinkler irrigation — this too will depend to a great extent on natural conditions, such as the composition of soils and the available slopes and command, but it will also depend on economic conditions and the skill of the water user. The simplest solution should be given preference so long as this corresponds to the requirements of the various crops. This applies also to countries which in the past were among the leading nations in the field of irrigation — for instance Mesopotamia, Iran and Central Asia — but where the skill of effective irrigation methods has been partly lost and is only slowly reappearing, partly through foreign influence. At least in the initial stages of development, and I am thinking of large scale development, the simpler methods of irrigation will have distinct advantages, if they are suited to the crops. In many traditional systems, flooding or border irrigation, is given preference. Already furrow irrigation needs great care and attention, especially in friable soils and on heavier slopes.

Sprinkler irrigation, which offers great advantages in light soils and uneven or sloping terrain, should be recommended to be applied only in cases where a proper servicing of the equipment — pumps, nozzles and pipe joints — can be assured. The same applies to use of tube wells for irrigation purposes. One would be inclined to say that tube wells should be used only in cases where the effective operation and maintenance of pumps, engines and screens can be assured and the already mentioned overpumping of groundwater avoided.

However, groundwater is often the only available source of water, the importance of which, not only for rural water supplies, but also for irrigation, is constantly increasing. It is therefore imperative that the difficulties existing in many countries regarding maintenance and operation of engines, pumps and transmission lines should be overcome.

Qanats versus Wells

The countries of the Middle East (Iran, Afghanistan, West Pakistan) and Central Asia and North Africa, use tunnels dug by hand, often many kilometers long, to supply water by gravity to towns and hundreds of thousands of hectares of land for irrigation. Their disadvantage is difficult maintenance, and that they are draining and exhausting groundwater permanently. In spite of their simplicity they are being replaced successfully by tubewells. Great care is needed to solve successfully this task of change over, which will interfere with existing water rights and traditions of water use.

Flood Irrigation

This type of irrigation (in its more primitive form "wild flooding") is extensively used in the Middle East, parts of North Africa, and elsewhere. It is practised mainly in cases where spates of intermittent streams are the main source of water and where storage is difficult for technical or other reasons. The weakness of the traditional system is generally the inability of the villagers to build diversion structures that could resist the impact of heavy floods. These systems could be greatly improved by providing suitable engineering structures. In most cases the villagers are well-organized and can take care themselves of the distribution canals and basins, which are often extremely well maintained.

The classical form of utilization of flood waters of large rivers — practised on a very large scale in ancient Egypt, presents advantages in many cases, and is reappearing in a number of cases.

Water Spreading

Water spreading for improvement of crops and pastures falls into the same category. These systems should not be discarded but the possibility of their improvement studied.

In many cases, spates and sheet run-off are the only possible source of water, especially where the torrents carry such a heavy load of silt that reservoirs cannot come into consideration. Underground storage of irregular surface run-off through waterspreading, successfully used in some highly-developed countries, should be promoted wherever conditions are favourable. This is relatively easy to introduce even under primitive conditions.

Use of Reservoir Areas and Natural Depressions for Irrigation Farming

When water is receding in reservoirs, the soil is generally soaked with water and conditions develop similar to those obtained in basin irrigation. In some of the developing countries this method is practised with success on a fairly large scale. The relatively shallow reservoirs in the Sudan are a good example of this type of "flooding". Reservoir water can also be lifted to the field as a supplementary source of water if required.

Irrigation Structures

The use of local materials should be recommended, however, the semi-permanent type of structures should be introduced with care.

It is highly desirable to improve existing conditions on many of the existing native systems.

It is well understood that in many cases especially in densely populated areas, improvement of existing irrigation systems cannot solve all the problems and the new land has to be opened up and brought under irrigation farming. It is also true that improvement of existing systems is in most cases a most difficult task. In order to make an old system more efficient not only poorly traced and built canals have to be rectified and provided with outlets and waste ways, but a large number of badly located and constructed diversion and intake structures removed. In most cases no substantial improvement will be possible without a considerable readjustment and reshaping of plots. Land and rights and water duties have to be changed to correspond better to actual requirements of crops and to the characteristics of the soil and to drainage possibilities.

All changes in the above-mentioned fields — however well meant and useful they might be — will meet in practically all cases the strong and even desperate resistance of the farmer. He has not been always fairly treated and is generally utterly suspicious of any proposals which interfere with his habits and rights.

But in spite of these difficulties, improvement of existing irrigation and drainage systems deserves far more attention than it had received until now in most developing countries. The advantages obtained from remodelling bad existing systems are so great that they deserve the greatest effort. Ease in operation, reduction of water losses, elimination of waterlogging and higher yields will repay efforts and investment.

Simplicity in operation should be one of the main objectives, when redesigning canals and structures. The more existing practices to which the farmer is used which can be maintained without reducing substantially efficiency and yield, the better.

Water saved through rebuilding the system and introducing more economical watering practices and rotations, will make water available for new areas or for greater irrigation intensity and the introduction of more remunerating crops. It will often be of great advantage to consult local farmers' associations when deciding on new methods and their help in implementing changes obtained.

As regards the type of structures such as regulators, spillways, offtakes and aqueducts for both new and existing irrigation systems and drainage works, these should be built in such a way that they cannot be damaged or spoilt by incompetent handling. Simple and strong structures and gates are esential unter conditions where no qualified personnel or frequent supervision exists.

In many cases efficient on-the-site supervision cannot be ensured and it might be of advantage to use prefabricated structures. Transport conditions and many other factors have to be taken into consideration when deciding the choice.

Simplicity, ease of operation and the least possible need for maintenance are the desirata. They are not always easy to reconcile with the need for safe and steady flow of water.

For the control of undisciplined or negligent users, and the reduction of wastage of valuable water, automatic gates, such as the Neyrpic modules and gates with upstream or downstream level control can be of great advantage. However, some of the devices are vulnerable if not controlled and checked properly. Modules giving permanent discharges under various heads can be recommended, although their cost might be in some cases prohibitive, especially for crops under irrigation which have not a very high market value.

Telecommunications should be introduced whenever needed. The question of telecommand, however, should be treated with caution. Lining of canals should be recommended wherever seepage losses are heavy, not only to avoid water losses, but also to avoid water logging and salinity.

• *Use of Water on the Fields*

Actual watering operations need the greatest attention.

The greatest weakness of irrigation in many of the developing countries is wastage of water. This is due as far as the technical part of the problem goes to bad land levelling and bad practices in distributing water from the field channels, cutting of the banks, and a mistaken notion that more water produces better crops.

It is therefore of great importance that proper control of water distribution should be achieved not only on the major canals but also on the field ditches. Syphons (plastic and other types) which are relatively cheap and easy to handle have been introduced recently on many systems to avoid cutting of canal banks and should be encouraged.

Land levelling at the initial stages together with a good layout of the field irrigation system in developing countries is even more important than in countries where efficient irrigation practices are already established, because farmers have often not the means to carry out this work themselves. These measures should therefore be properly planned by the Government and the organizations in charge of irrigation schemes.

The main technical weakness of most irrigation projects in developing countries is that the water is not brought to the farmer but that only major and maybe secondary canals are built: already the tertiary canals are left to the local population which is not organized to carry out this work properly. The tendency not to include in engineering projects (and in their cost estimates) field systems, is often dictated by the desire not to show high per hectare investment costs. This is of course no excuse for making a project incompletely.

The importance of good land levelling and land preparation cannot be over-emphasized. Together with effective drainage, it is the key to better land use and higher yields.

Drainage Design, Drainage on Irrigated Land

If good irrigation is important, even more important is the creation of an adequate drainage system in irrigation projects, especially in the arid tropics where salinity is a major danger.

Until very recently, in many developing countries, drainage works were badly neglected. Government activities were limited to the creation of the major irrigation structures and except in certain cases and, even then normally far too late, main drainage collectors were built without providing any adequate field drainage system. The result was waterlogging and salt accumulation, and the destruction of thousands of hectares of high cost and potentially highly productive land.

As regards the type of drainage which can be recommended, this will vary from case to case: tile drainage, which has many great advantages both from the hydrologic and agricultural point of view (open drains create difficulty in cultivation such as for communications) is expensive and can be economically justified when the returns are sufficiently high to pay for the expensive drainage.

Drainage of Marshy and Waterlogged Lands

Apart from the economic value of drainage works, there are no major differences between such works built in highly developed and developing countries. Drainage of peat soils in developing countries deserves special mention. Whereas such soils are in highly developed countries situated to a large extent in the temperate zone, peat soils in semi arid conditions are predominant in developing countries. In hot climates the drainage of peat soils presents major problems. Excessive shrinkage, the loss of soil structure, have often been experienced when drainage has not been undertaken with the necessary caution.

The remarks made earlier regarding use of mechanical means for irrigation apply also to drainage.

Tidal Land Reclamation

When recommending construction of tidal polders, preference should be given to simpler solutions and smaller schemes, distribution over the tidal reaches in such a way that it could be assimilated by the population without major organizational efforts. Schemes which can be carried out essentially with local means should be given priority over schemes requiring major foreign aid in terms of equipment and funds, so long as the expected returns are favourable.

Construction Materials

When selecting construction methods and materials many factors have to be considered. The lack of skilled labour and the necessity to employ large numbers of local unskilled labour, the lack of foreign exchange for imported materials and equipment and difficulty of transportation are all factors which will influence the design of projects.

Conditions will vary from country to country. The lack of good sand and gravel and stone will further the use of bricks for structures in the same way as it did in the past in some countries in Europe until recently. The lack of fuel on the other hand will speak against this solution. Brick kilns, using wood for burning bricks have contributed to deforestation of large areas as much as any other factor.

Stone masonry will prove advantageous, where good stone masons are available, economy on the use of cement desirable and timber and steel shuttering locally unobtainable or expensive.

If good timber is available wooden regulators and other structures will in many cases have the advantage of easy transport and construction, but they need good maintenance and this may exclude their use in many cases.

The great contradiction existing in many developing countries, between the need for strong structures and installations requiring little maintenance, and the need (for economic reasons) to find unexpensive solutions, is difficult to solve.

Locally available material, and local labour, will continue to play an important role in the design of smaller structures of irrigation and drainage works and in the construction of canals and drains.

As far as large structures, such as dams, weirs and pump stations are concerned, the increasing availability of foreign capital help for the purchase of equipment and construction from abroad will eliminate to a great extent the differences between structural design adopted in highly developed and developing countries.

Non Technical Factors

Personnel

The greatest obstacle to the success of irrigation and drainage schemes in most developing countries is not technical. It is the lack of well-trained permanently employed technical personnel. It is not that the country would lack able university-trained engineers, but very few of the developing countries possess a well-organized and well-staffed administration able to carry out design, construction and, which is even more important, to supervise operation of large irrigation projects.

The reasons for this are manifold and vary from country to country. The most serious is the low salaries paid by the Government administrations to their technicians, combined with the possibility to earn much higher incomes in other branches of administration or in private enterprise.

The second is often poor organization and complicated structure which does not give able and dependable technicians sufficient authority. The sence of frustration among able technicians is often very great. When one follows the career of any engineer or agronomist in some of these countries, one can see how an able and devoted man deteriorates because of frustration, or leaves the administration, losing all hope that he can build up an interesting and worthwhile career. Shifting of available personnel continuously from one job to another is another difficulty which is an endemic evil in many administrations.

How foreign aid can help over this is difficult to visualize. The temporary replacement of non-available local senior technicians by foreign personnel can help the country to develop certain schemes and bring them up to the operational stage, but there must be a time when operations have to be taken over by a competent national organization. And if the local technicians are not connected actively with the project at a very early stage, it will be very difficult to operate the project successfully before it runs into heavy difficulties.

Training should not be limited to high level specialists.

There is no lack of fellowships and scholarships granted by the various international and bilateral aid programs to Governments. However, the selection of fellows as well as their re-employment by the respective agencies on return from abroad needs to be improved, otherwise the specialist in spite of his improved training will not fare better than his colleagues who were not sent abroad, but are not properly utilized in their jobs.

Care must be exercised also when selecting the country and institution where the technicians are sent. Very often the specialist trained abroad is unable to fit into his home environment on return, and this happens to a greater extent to the abler men, who often leave the service, or even remain abroad and are lost to their country.

In view of this danger it might be advantageous to send trainees and students where conditions are similar to those prevailing in their own countries and where they do not become uprooted: and to put more emphasis on an "on the job" training, where specialists do not lose contact with their countries.

In the field of irrigation and drainage, such training could be given successfully on pilot and experimental farms, where technical personnel as well as technical administrators could be trained for future service in Government departments and in irrigation and drainage associations, and also for work on private farms. Such pilot or "model" farms could be built especially for training and demonstration purposes and could include laboratories, classrooms and if required living accommodation.

The training of lower grades, such as water bailiffs, farm extension workers, etc., is probably more important in most of the developing countries than the training of engineers and highly qualified agronomists, because it is really the lower layer which is more missing. The German examples of schools for artisans which were at a certain period organized within their technical assistance program in a number of countries, was a step in the right direction, but was in an associated field.

There is of course one solution which could help over these difficulties at least for a certain period, during which organizational and administrative structure could be improved — this could consist of the use of the services of foreign consulting firms or foreign aid programs for the planning and design of irrigation drainage projects.

Relations between various Groups of Specialists

These relations are often not sufficiently well-defined and in case they are, it is not always for the advantage of a successful job.

In many cases, including some of the former colonial administrations, it was the engineer who was essentially responsible for the planning and even more for the actual execution of hydraulic land reclamation works. These engineering departments were in many cases well organized and administered. The economic assessment and financing was looked after by the Finance departments, but the agriculturist

— the actual water user — had not a sufficient say in the question of design and operation. These conditions remained and often became worse in newly-independent countries after the departure of the foreign technicians and administration.

In many of the developing countries, irrigation services are manned almost exclusively by engineers. They are neither soils specialists, agriculturists nor land use economists attached to the service.

There are other cases where irrigation projects, if not departments are operated by generalists utilizing engineers and agronomists in the direction established following preconceived solutions. What is forgotten in these cases is the value of technical inventiveness and initiative leading to new solutions.

The lack of understanding of the importance of other disciplines is an evil which is not limited to developing countries; but in their case it causes more harm than in countries where through past mistakes things have improved to a certain extent.

In the field of irrigation and drainage, the French or the Dutch type of education producing the "ingenieur du génie rural" is very well suited for developing countries, because they combine knowledge in the field of hydraulic engineering, in soil science, agronomy and technical administration.

Relations between Various Administrations, Responsible for Planning and Operation of Irrigation and Drainage Schemes

What was said on relations between subject matter groups applies also to the various ministries, departments and agencies.

Here again, conditions are not always more satisfactory in highly developed countries than in developing ones.

Various solutions have been tried out, not always with success. Special authorities have been created for large projects or for entire regions and even countries. Whilst these authorities presented certain operational advantages against more cumbersome procedures of Government departments it often cut the projects away from contacts with existing services, possessing practical experience as well as research facilities. It would lead us too far to attempt an appraisal of advantages and disadvantages of one or the other solution.

In developing countries, the lack of contacts and coordination in the planning as well as in the operational stage between the various ministries can be extremely harmful.

A few examples can illustrate the dangers of such a state of relations: — In one case more than one hundred storage reservoirs were built by the country's irrigation department, whose task ended with the provision of the water in the reservoir. The distribution of water to the farmer, on the other hand, was the responsibility of another department — that of rural cooperation. The latter had neither the necessary technical staff to design the distribution system nor to assist the farmer in utilizing the water. The problems could have been solved by cooperation between the two administrations, but unfortunately such cooperation was sought by neither of the two parties.

In another country reservoirs with a total storage capacity of 3 billion cubic meters were built by an agency specially created to provide water for irrigation and livestock in a large arid area, with no proper organization to utilize the water. As a result reservoirs are filling and evaporating every year without any utilization of the water.

Coordinating or steering boards and committees are often used to ensure comprehensive planning and coordinated execution, but only in few cases has this solution proved effective.

Operation of irrigation and drainage projects is a complex and difficult task. The solutions adopted today in the more advanced countries are the result of slow, organic development. They vary from country to country, but have one characteristic in common — the farmer and farmers associations are participating actively with actual operations.

In developing countries the organizational form, best suited to local physical, economic, social and in many cases also to political conditions, has still to be found. Much will depend on the scale of available managerial skill, experience of the farmers, but also on crops and soils or topography. A combination of a number of factors will decide which solution is more suited to the individual case.

The estate type of farming might be favourable for certain industrial crops or for heavy soils, where mechanical equipment is required for cultivation. This might be also the case when in flat open country mechanized farming represents an economic advantage.

For the same conditions tenant farming directed by a competent management might be an equally good or even better solution.

The Sudan Gezira scheme is often quoted as an example. On this scheme water is provided by the Government from the Nile storage dam at Sennar. The distribution of water and maintenance of work is also the responsibility of the Government. Heavy ploughing was done originally by a foreign concessionaire, today by an entirely Sudanese "Gezira Board", which is also doing the ginning and marketing of the cotton. Cultivation and cropping is done by the tenants. The income from the sale of cotton is distributed in a fixed proportion between tenant, Board and Government. The revenue from food crops belongs entirely to the tenant.

In countries where irrigation and polder schemes are new and the cultivator does not have the necessary experience and where local managerial skill in this specific field is absent, concessions to experienced foreign agents might be a good solution as it will in most cases provide the capital needed for development. A good example for this solution is Ethiopia where recently several large concessions have been granted, or are under discussions.

One of them is the Wonji project where the Government entrusted a Dutch private group with the construction and management of a sugar cane plantation and also with the construction and operation of sugar factories.

Another is a large cotton estate managed by a British group in the same river basin.

In Ghana foreign concessionnaires have been invited recently for the management of irrigation schemes for sugarcane and construction and management of sugar factories.

In Somalia and Afghanistan irrigation model farms 5 to 10,000 hectares are being established under Soviet management and with financial assistance.

There are of course many similar cases in other countries. The examples mentioned above are interesting because they have been initiated in countries of differing social and political structure by Governments jealously guarding their country's independence.

In a number of developing countries land reforms are carried out making former tenants or farm labour, owners or lease holders of land. It is extremely important that when the changeover is made which leaves the former tenant in many respects with less assistance than he had before, the Government step in and create an adequate organization.

In irrigation, drainage or polder schemes this is especially important as the maintenance of canals, dykes and structures is beyond the capacity of farmers and small farming communities.

Water Rights

In many of the developing countries, the right to use water is regulated by tradition or in the case of colonies or mandated territories by laws introduced by the Government responsible for the country's administration.

In a large number of cases the traditional rights as well as the existing laws and ordinances, governing water utilization in developing countries do not correspond with the changed conditions. This applies not only to surface water, but to an even greater extent also to groundwater, where recent technical progress resulted in very intensive utilization of groundwater basins.

Much harm has been done already by uncontrolled overpumping of groundwater reserves and introduction of effective control is of extreme urgency.

However, it is not sufficient to create adequate laws regulating the use of rivers, lakes, reservoirs and groundwater resources. Even more important is the practical implementation of these laws by an effective water administration which at present does not exist in many countries.

When granting water rights, the Government should be in a position to decide where in the interests of the country or a river basin water can be used with the greatest advantage and not commit water to areas where the soils or other factors are not favourable and leave without irrigation water the more promising areas.

Developing countries should pay much more attention when granting water rights than they have done up to date.

This concerns of course not only irrigation and drainage schemes, but all other uses. However, irrigation is the largest "user" of water in the sense that it actually uses up the water, contrary to water power, where water utilized can be used again; or industrial use, where pollution is one of the major problems.

Health Aspects

With the increase of areas under irrigation, the danger of the spreading of waterborne diseases has increased considerably. Bilharziasis and other waterborne diseases are in many countries a major health problem. Apart from the use of chemicals, proper water control in canals is considered today the best polliative. When designing irrigation and even more drainage schemes, health specialists should be consulted.

Economic Aspects

It would take us beyond the scope of this paper to discuss the criteria, governing the economics of irrigation and drainage projects in developing countries. For large scale schemes decisions are taken, as a rule, by Governments within the framework of their development plans.

Our main concern here is that no decision should be taken on actual implementation without a feasibility report based on sound basic data, dependable engineering design and cost estimates, and realistic agricultural production and price figures.

It is equally important that the methods of operation and administration of the scheme, including settlement and tenure forms, water rates, should be decided upon, as they greatly influence the economics of the project.

Political pressure, combined with a genuine urge for immediate large scale development. apparent often in countries gaining independence, leads frequently to implementation of projects which have not been studied in sufficient detail in all their aspects. Technicians are not always in a position to resist such a tendency, but at least they should do their best to direct the projects in a sound direction.

Role for Foreigns Agencies

A large number of agencies both bilateral and international are engaged today in technical assistance work in the field of hydraulic reclamation as in many other fields.

As regards the impact of assistance given by foreign agencies, this will depend more on the ability of the developing country to absorb and make use of foreign assistance than on the work of the agency itself.

Present shortcomings are as much the result of lack of coordination and harmful competition as of inability of the Governments to make the best use of assistance, and in some cases the reluctance to bring about direct cooperation between the various aid-giving agencies.

Government requests on some projects often go to several agencies. This can only be avoided if the activities of all participating in technical and capital assistance are coordinated. But it is not sufficient to avoid duplication. It is necessary to make information and data obtained through the work of one agency available to the others. This would increase the value of the work of all of us and make it more valuable to the recipient Government. Unfortunately this is not always understood by them.

There are obvious political reasons for competition and reluctance against cooperation.

We in the United Nations are probably in a better position than any national agency to improve cooperation, but we need help from the others.

This paper deals only with questions relevant to technical assistance programs and does not treat policy matters related to capital assistance. The United Nations aid programs, apart from the activities of the International Bank and the IDA are generally limited to technical assistance and projects leading to investment. However, it is important that close relations should be established between capital aid and technical aid programs.

The services of the United Nations should be utilized to bring about a closer relation between the two programs, making available valuable information supplied by technical assistance work to Governments and foreign agencies financing actual development.

Summary and Conclusion

1. Irrigation and drainage projects require the continuous participation of large masses of the rural population. Design and operation has therefore to be adapted to the existing conditions and available skill to a greater extent than in other hydraulic works; in spite of the fact that basic technical solutions are essentially governed by physical factors and will be similar in highly advanced and developing countries.
2. In view of this intensive participation of the local population, simpler solutions should be given preference whenever efficiency can be maintained.
3. Local labour should be used as much as possible both during construction and operation instead of mechanical means to provide employment for surplus labour. Local materials should be used to save foreign exchange.
4. The great difficulty in designing irrigation and drainage work is that in most cases economic returns from projects are not sufficiently high to justify expensive solutions and at the same time structures must be strong to compensate for generally poor maintenance and operational practices.
5. In most developing countries large projects are given preference over smaller new projects and even more over improvement of existing schemes, although the latter offer often great economic advantages as they do not require costly infrastructure.
6. As a result of pressure for immediate implementation, preliminary surveys are often neglected causing faulty design. Much more attention should be given to soil investigations, agronomic and market studies, as well as land use and socio-economic sur-

veys than is generally done. No project should be started without an adequate feasibility study.

7. A deficiency most common in irrigation projects in arid and semi-arid regions is the lack of adequate drainage, an omission causing serious salinity and alkalinity problems, difficult to repair. Field irrigation and drainage systems are often missing in the original design and are left to the farmer who has neither the knowledge nor the means to build them properly. The same applies to land levelling, so important for the economic use of water and higher yields.
8. All these and other deficiencies are due mainly to the absence of well-organized irrigation and drainage administrations, manned by competent and sufficiently well paid permanent technical personnel. Relations between the various subject matter specialists are often not clearly defined. This is caused partly by lack of co-ordination between various Government departments concerned with irrigation and drainage schemes.
9. These deficiencies make themselves felt even more on the operational side. Several methods have been tried, such as operation through Government departments, autonomous and semi-autonomous authorities, farmers associations and concessions to foreigners. This last can be considered as a good temporary solution, especially if it is connected with training and if a take-over by a local administration can be ensured at an appropriate date.
10. There is plenty of scope for useful foreign aid needed during the difficult initial stages of development. Such aid is needed in the form of foreign experts, training of local technicians, supply of equipment and also as capital assistance. However, foreign assistance needs much better coordination than it has at present, where very often competition and duplication reduces efficiency.

References

Papers presented to the United Nations Conference of Science and Technology for the Benefit of Less Developed Areas. Geneva, 1963.

1. *Hagan*, Robert M.: Transforming Irrigation from an age-old Art into a modern Science through Research and Technology. E/CONF. 39/C/454.
2. *Zhechev*, P.; *Filyov*, V.; *Delibaltov*, I.; *Hristov*, H.; *Tsonev*, I.: Utilization of the Water Resources for Irrigation in the People's Republic of Bulgaria. E/CONF. 39/C/172.
3. *Russell*, G. C.: Irrigation and Water Use in Southern Alberta. E/CONF. 39/C/135.

4. *Diaz Vial*, Carlos: Soil Reclamation Research Programme in Chile. E/CONF. 39/C/512.
5. *Prasad*, Mahavir: Problems of Irrigation and Water Use in India. E/CONF. 39/C/106.
6. *Boaz*, M.: Irrigation Problems, Practices and Advisory Work in Israel. E/CONF. 39/C/461.
7. *Mitchell*, Peter K.: Irrigation in Sierra Leone: Possibilities and Prospects. E/CONF. 39/C/6.
8. *Garcia Lozano*, Faustino: Irrigation, Use of Water. E/CONF. 39/C/280.
9. *Ozal*, Yorkut: A Review of Irrigation Development in Turkey. E/CONF. 39/C/261.
10. *Zekhidov*, A.; *Benyaminovich*, E. and *Ozersky*, E.: Technical and Economic Aspects of Irrigation and Drainage of the Golodny Steppe. E/CONF. 39/C/339.
11. *Elgabaly*, M. M.: Irrigation and Water Use, In UAR. E/CONF. 39/C/161.
12. *Vladislavjevic*, Zivko: Irrigation and Other Uses of Water. E/CONF. 39/C/292.
13. *McDowell*, G. E.; and *Slayter*, R. O.: Irrigation and Water Use under Tropical Conditions with Special Reference to Irrigation in Tropical Queensland. E/CONF. 39/C/389.
14. *Kamal*, Ahmed Ali: The Control and Distribution of Irrigation Water in the UAR. E/CONF. 39/C/137.
15. *Darlot*, A.: Assessment of Flow from the Equipment of Irrigation Installations by a Frequent Survey of Requirements: Experimental Estimate of Requirements and of Irrigation Methods. E/CONF. 39/C/147.
16. *Hoare*, E. R.; and *Fleming*, P. M.: Sprinkler Irrigation: General Design Considerations. E/CONF. 39/C/329.
17. *Chin*, L. T.: The Practice of Rotational Irrigation in Taiwan, Republic of China. E/CONF. 39/C/259.
18. *Darlot*, A.: Methods and Criteria for the Preparation of Soils for Surface Irrigation. E/CONF. 39/C/96.
19. *Charreau*, C.; and *Sene*, D.: An Experiment in Irrigation by Sprinkling in Senegal. E/CONF. 39/C/504.
20. *Penman*, H. L.: Supplementary Irrigation. E/CONF. 39/C/29.
21. *Penman*, F.: Salts in Irrigation Agriculture. E/CONF. 39/C/418.
22. *Tamhane*, R. V.: Reclamation of Usar Lands: Saline and Alkaline Lands of India. E/CONF. 39/C/100.
23. *Rigi Puperti*, Agostino: The Part Played by Artificial Lakes in transforming Hill Farm Irrigation in Arid Zones. E/CONF. 39/C.
24. *Boyer*, J.: Determination of Water Requirements of Plants: Application to Coffee Growing on the Ivory Coast. E/CONF. 39/C/337.
25. *van der Meer*, K.: Soil Survey Problems concerning Irrigation and Irrigated Agriculture. E/CONF. 39/C/86.
26. *Jackson*, J. K.: The Use of the Water Budget in Tropical Forestry with Particular Reference to the Sudan. E/CONF. 39/C/239.
27. *Ivitsky*, A. I.: Methods for the Reclamation of Swamps. E/Conf. 39/C/432.
28. *Chin*, L. T.: The Organization and Operation of Chianan Irrigation Association, Taiwan, Republic of China. E/CONF. 39/C/174.

V. Special Problems on Water Development in Less Developed Areas

by K. L. Rao

Part I

Characteristic Demands on Design and Construction of Major Works in Less Developed Countries

Introduction
Salient Features of Development Works in Less Developed Countries

Since the industrial revolution, three centuries ago, world has changed considerably in its concept of the prosperity of a nation. Only a nation whose resources are developed and fully exploited is now considered rich. However, the nations which entered the stream of rapid industrialization developed greatly, while the other nations remained stagnant and poor. Curiously enough, most of the less developed or undeveloped countries are all located in and around the tropical zone.

India with a sixth of the world's population is typical. Three hundred years ago, it constructed one of the wonders of the world, "The Taj Mahal", and attracted many European countries on account of its fabled wealth. India, however, did not enter the industrial movement and went downhill economically. It is only during the last 40 years, which almost coincides with the period of the struggle for political independence, that she woke up to the importance of the resource development, specially of water resources. But it was not till the dawn of independence, in 1947, that serious efforts commenced to tap the great wealth cf India's rivers. Since then there has been a sudden spurt in water conservation and utilization. And this is true, more or less of other backward, newly freed nations. Each newly liberated but backward country suddenly finds itself a nation in a hurry, a Rip Van Winkle in an amazing world of Science and Technology. This leads to an important observation that less developed countries will embark, as a result of political independence, upon a course of sudden and fast development of resources. The works will therefore be required to be done on a massive and speedy scale, allowing little time for adequate investigations and planning.

There is another inherent difficulty these countries have to face. The works require large sums of money, which they lack. Many other developmental activities besides engineering works compete for finance. The result will be that heavy taxation and foreign loans will have to be resorted to. In India, for the 15 years from 1951, a total amount of Rs. 15,200 crores is being spent, of which nearly 62 per cent is for engineering enterprises.

A large number of scientists and engineers are required, more than the normal output of the country. This again imposes problems of expanding educational facilities and sending abroad their young men. Thus in India, prior to 1947, there were 38 engineering colleges and 53 polytechnics, catering to 2,940 degree engineering and 3,670 diploma students. Now the engineering colleges have increased to 102 with an intake of 13,820 and polytechnics to 195 with an intake of 25,800 students. By the end of the Third Plan, it is expected that facilities will be provided for an intake of 20,000 degree and 40,000 diploma students. Nearly 7,000 students are studying in foreign countries. Thus when dealing with less developed countries, one has to bear in mind the obstacles of finance and technical personnel which act as a drag on the tremendous urge of the nations to race forward with as many developmental projects as possible.

Engineering Handicaps

In planning river valley projects in less developed countries, there are difficulties, both natural and inherent. As stated earlier, the less developed countries are mostly located in hot climates, and therefore their river systems offer distinctive problems. Thus the rivers carry widely varying quantities of water during the year. Torrential rains occur in a few months of the year and drain off quickly. In the Godavari River (India), the maximum flood discharge recorded (1952) was in excess of 2.8 million cusecs. The yearly variation in a normal year between the maximum and minimum discharges is 1,000 in the Godavari and similar peninsular rivers. As we go north towards the Himalayas, the variation is less, as these rivers get a portion of their waters from the snow melt. Thus the ratio between maximum and minimum flows of the Sutlej in a year comes to 100. Nevertheless, the variations are still far greater than in the case of rivers in temperate zones. For the River Rhone, the maximum discharge is only four times the minimum. The uneven flow and the very large maximum discharge of rivers in less developed countries call for special attention in design and construction of diversion and spillway works. For planning diversion works on the River Nile (annual discharge 67 million acre ft.), tunnels have been provided because the maximum discharge to be catered for is only about 0.47 million cusecs. But for the Nagarjunasagar dam on the Krishna River, no diversion tunnels could be thought of, as the maximum discharge is more than a million cusecs. The river course itself has to be utilised, with the result that work is continually interrupted and the construction plant layout has to be modified making allowance for the same. In the case of the Himalayan rivers, though the rivers carry equally large annual discharges, tunnel diversions are possible because of a reduction in the maximum flood discharges. Thus in Bhakra with a maximum discharge of 0.35 million cusecs to 50 ft. diameter tunnels were provided for diverting waters for the construction of the Dam.

Lack of observations and data on rivers is another source of difficulty in assessing annual yields and maximum discharges of rivers in less developed countries. In the absence of field observations, empirical formulae have to be used. The methods in general use for determining maximum discharge and annual flow are from formulae of Dickens, Ryes and Inglis, and evaluation by rainfall — run off method, and Stranges Tables. Thus in India, there are gauge readings kept for a few rivers for periods of up to sixty years as for the Cauvery, Krishna and the Godavari in the South, and Ganga, Ravi and Sutlej in the North. But for many other rivers, there is a total lack of data except for the observations in recent years. This is a great handicap.

The works in the tropics are generally storage works, and unless a fair approximation of the quantum of river flow is known, defective projects may be planned. Nevertheless, progress on developmental works need not be held up. Even with observations of river flows over a few years and some meteorological data in the watershed, it would be possible to construct a fairly good hydrological picture of the river. Many of the projects undertaken in the last few years were prepared on this basis and have proved successful. Even the failures of the earth dam at Panshet and the composite dam at Kaddam, both by overtopping, cannot be attributed to defective studies of hydrology. Many of the works, such as the Lower Bhawani, Tungabhadra, Rihand, Bhakra and the DVC, have proved the reliability of the methods used for calculating spillway discharges. It is easy to overestimate the spillway discharge to be provided, but this will at once raise enormously the cost of structures. Hence it is necessary to carefully consider the various aspects. This is of special importance when dealing with river problems in tropical countries.

Major projects require detailed investigations to provide data for economical designs. These investigations cover topographical surveys, engineering studies of materials of construction, subsurface investigations by bore holes and geophysical techniques and exploratory field experiments. In less developed countries, enough facilities are not available to collect the necessary data. Even in India, in spite of an extensive network of laboratories, drilling riggs are not available readily as also large, special equipment such as triaxial testing machines for big sized soil samples, etc. Similarly the equipment required for tests on rock has to be imported from outside.

Geophysical investigations are proving quite valuable in trying to find out subsurface rock depths in India. The latest type of field equipment in which the depths to rock can be determined with mere hammer blows, instead of explosives, is not available in India. Similarly a good earthquake engineering laboratory equipped with machines to determine the data for earthquake resisting designs is lacking in India. It is notable that some of the most severe earthquakes of the world, of the order of X and XI on the modified Mercalli scale, occur, though at infrequent intervals, in the northern regions of India (i. e., in Bihar and Assam). The dam at Barapani near Shillong (Assam) and Kosi Barrage (Bihar) were designed to withstand severe earthquake forces. But these were based more or less on empirical studies. No model studies on shaking tables were done. A large number of earth dams such as the 350 ft. high Beas Dam (Punjab) and 410 ft. high Ramganga Dam in U. P. have been sanctioned and are about to be taken up for execution. In both these cases, it would indeed be extremely valuable to determine the behaviour of the structures under earthquake conditions. A small beginning has been made in the Roorkee University laboratories.

Another field in which large assistance is required for modern designing is the field of hydraulic testing. Hydraulic model studies are most essential to evolve economical and hydraulically stable structures. For these, extensive hydraulic laboratories are necessary. In less developed countries, hydraulic model laboratories will not exist to the extent required. Fortunately in India, there are 17 laboratories in the States and a Central Laboratory in Poona. These are extremely useful. In preparing a simple and yet most successful design for stabilizing the Brahmaputra River at Dibrugarh, hydraulic model studies were done and the result was used in the prototype. This led to a most successful training measure for the mighty river whose minimum flow at Dibrugarh is 0.2 million cusecs and maximum is 1.5 million cusecs. In less developed countries, there is the great handicap of the time lag between the development of new techniques in the world and their adoption. Thus in the field of hydraulic model testing there is a substitute technique recently developed which requires much less model work. This is known as the "Analogue method" and the model is called the mathematical model. This is being adopted for the flood studies of the River Mekong in Cambodia. The technique is specially useful where field data are meagre and where a limited objective such as flood stages under different conditions of flow are required.

There is still another great handicap for relatively backward countries when designing major works. This is want of specialists. In less developed countries, there may be adequate number of engineers, but every now and then problems arise which require consultation with foreign specialists in the line. In India this is felt very keenly. At the Rampadasagar dam site on the Godavari, investigations were in progress to determine whether open excavations can be done for depths up to 200 ft. below the bed of the river. Profuse seepage of water was expected and slopes of excavation had to be determined. An experimental pit 30 ft. deep was put in and observations of slips that occurred were taken. Dr. Karl Terzaghi had to be called in as Consultant to advise on the coffer dam excavations. Similarly for the construction of the Beas Dam, a 350 ft. rockfill dam in a zone of comparatively poor rock, foreign expert advice is being sought.

Special Technical Features of Design

There are some special and characteristic features about major works in less developed countries. In the construction of dams, for example, concrete is invariably used in Europe and other advanced countries. In India, it is costlier to use concrete than stone masonry. In special circumstances, as for Bhakra Dam, where there is no good stone available, concrete was adopted. In Southern India, where plentiful supplies of good rock is available, masonry construction is adopted. There was a controversy on the material for the construction of the 350 ft. high Nagarjunasagar Dam. The main argument advanced against the use of stone masonry was that no test results of stone masonry strength were available, while with concrete there is a lot of data. Experiments were therefore done with stone masonry cubes of 3 ft. sizes in India and in U. S. A. Special machinery was rigged up in India in a tunnel, the reaction in testing being taken up by the tunnel roof. The tests showed that stone masonry was quite as strong

Hence Nagarjunasagar Dam is now being built with stone masonry. Stone masonry is cheaper in India because less cement is involved and cooling measures need not be undertaken. Also, much less mechanization is required than for concrete. It offers an advantage to less developed countries which depend on foreign countries for construction machinery.

During my visit to Germany in 1956, I happened to see mechanised masonry (also called masonry concrete) being used in Eder and Oker dams. On my return to India, I advocated its use and an application of this is in the construction of the Koyna Dam near Bombay.

Also, to reduce the cost by using reduced cement content, pozzalanas are employed. Thus in Bhakra Dam, shale was ground to the fineness of cement and mixed in cement concrete, replacing 10 to 20 per cent of cement. In the rest of India, clay is burnt in the form of bricks, then powdered and used for replacing cement to the extent of 20 per cent. This not only reduces the cost, but also improves its water tightness. Air entraining agents have been developed at various dam sites and these are used to obtain better workability. Thus in less developed countries, materials of construction which will ensure cheaper costs have to be adopted. This is particularly possible because labour costs are small compared with Western countries.

Earth Dams are cheaper than masonry structures in less developed countries. Till recently, it was believed that earth structures are not as permanent as those of masonry. Besides, the new soil science had not yet come to be known widely, and engineers were afraid to adopt earth structures above 50 to 100 ft. New techniques of selection of materials, grading, placement, tamping and field control have all contributed to adoption of earth dams even to great heights. But as misgivings are prevalent with regard to the safety of earth dams, it is necessary to establish modern soil laboratories and demonstrate by examples how earth dams do not fail generally and that the same degree of safety is attained for earth dams as for masonry.

In respect of the free board for earth dams, as also for masonry structures, it is better to be more liberal, specially in the first phase. This is to obviate any underestimate of floods, sudden onslaught of flood waters, and as a safeguard against any careless, temporary operation of spillway gates. In Western practice, a free board of 6 ft is considered ample for concrete dams, while in India, twice the figure would be adopted.

For vital features, possibilities of failures must be visualised and precautionary measures incorporated. Also local talent must be built up to deal expeditiously with unexpected situations. Thus in the

Bhakra Dam, the right tunnel was fitted with hydraulic hoist gates to regulate the flow of water to the lands below while the dam was being constructed. When the water level in the reservoir rose to 270 ft. above the bed level, there was a failure of the bonnet in the hoist chamber and the hoist gates were thrown out and the water began to flow unregulated through several galleries of the dam. The water found its way into the Power House and a situation developed which posed a great threat to the Project. By throwing in concrete blocks and earth into great depths of water in front of the entrance to the tunnel in a dexterous manner, the flow was stopped and control regained over the system after five months of strenuous work. The local talent developed so well that Indian engineers could deal with one of the most difficult engineering problems, by an original method, and in a very short time.

Control gates for reservoirs should be designed sturdier than usual. This is to provide for imperfect field workmanship and subsequent maintenance. Thus while radial gates may prove cheaper in most of the cases, lift gates would prove more acceptable in view of its being able to stand up to rough handling. High head gates must be provided in as few cases as possible, for the manufacture of high head gates is inadvisable in less developed countries. It is far better to provide gates for operation up to 75 ft. head. Beyond this, cavitation and vibration tend to be set up unless the designs of the gates are hydraulically sound and manufactured in good workshops. Provision of hydraulic hoist gates must similarly be limited to cases where alternate methods of outlet will prove far more costly.

Foundation treatment, both rock and earth, under the dam is another field where the practices in less developed countries are different. Invariably, in advanced countries, earth foundations are not normally disturbed and grouting techniques are adopted to render the foundations impervious. Thus in Serriponcon and Matmark dams, grouting techniques were adopted instead of removal of foundation earth. In less developed countries, such facilities for grouting would not be available and open excavation and removal of earth for foundation has to be resorted to. But where grouting consultants are available, it can be adopted, as was done for the Kotah Barrage (India), where sixty feet of river bed consists of earth, sand and big stones. Clay and cement grouting was successfully applied and the reservoir is now standing with a depth of 120 ft. water with absolutely no seepage through the foundations.

For hydro-electric projects, and in thermal power stations, the size of the units must have to be kept small or medium. Bigger sizes may present many difficulties in transport either by road or rail, as both systems may not have been geared for the purposes. Also it requires considerable experience to operate successfully big units. As the total installed capacity in these countries would be small, a big size unit should not normally be added. In the event of its failure, great dislocation will occur to industries utilising power.

The design of power houses should be particularly simple and allowances must be made for imperfect field fabrication of penstocks, etc. Incorporation of duplicate and alternate safety methods is advisable.

Possibilities of corrosion and passage of big sized particles through the turbines must be considered and the machines must be rendered safe against them as subsequent repairs cannot easily be arranged for. The manufacturers will perhaps be several thousand miles away from the place where the machine is used. For all equipment, it is better to keep an extra stock of spares at the time of initial ordering.

In providing shell roofs, and prestressed structures, considerable detailed designs and drawings must be provided for the engineers in the less developed countries. It is realized that considerable economies will result by adoption of shell and precast techniques, but quite a few failures of structures happen and prejudices get built up against new methods. It is therefore most essential that excellent consultation services be made available before special types of construction are designed.

Alternate studies have to be made to determine the type of construction which will prove cheap in the country. In India, in the construction of tunnels for irrigation systems, etc., the costs are greater generally for tunnel excavation than for open excavation up to 100 ft. depth of overburden. On the Nagarjunasagar Canal, the tunnel is confined only to places where excavation is in excess of 100 ft. into rock. Similarly, concrete lining of tunnels are costly. Hence lining of the tunnel should not be done as a matter of course, but relative studies of a bigger tunnel versus lining of canal, etc., should be made.

In irrigation canals, greater discharges can be pushed through by lining the bottom and sides, and also considerable water loss, up to 25 per cent, can be saved. But lining is costly in the absence of mechanization and hence comparative cost estimates have to be made whether a canal has to be wide or lined.

In irrigation canal systems, there will be hundreds of small structures such as drops, cross-drainage works, etc. By present conventional methods, building each small structure is costly. Instead, precast techniques can be employed with profit. These have to be developed to suit the economy of less developed countries.

Special Technical Features of Construction

In less developed countries, most of the construction machinery has to be obtained from abroad. When machinery is thus got, there will be some uncertainty in drawing schedules of construction due to delayed deliveries of machines or their improper working. Oftentimes, spares have to be obtained even by air freight. Unless operators are specially trained, the outturn also will be less. These various factors must be borne in mind when drawing up construction procedures.

In the construction of large earth dams, involving long leads for conveyance of earth, earthmoving machinery is inescapable. In designing earth dams, however, materials which have to be borrowed from long distances must be provided to the smallest extent necessary and earth sections altered to use material nearby.

Manual labour will be used on constructions, more than in advanced countries. Hence, when drawing up plant lay-out, operation by manual labour has to be liberally provided for. There should be less of automatic controls.

Erection staff for power plants will have to be obtained from outside and therefore proper schedules must be drawn up well ahead.

As the labour force will be considerable in large projects, careful consideration has to be given to the amenities and redressal of grievances. Adequate administrative apparatus has to be set up for ensuring smooth relationship between labour and management.

In the initial stages, generally electric power will not be available for construction. The construction equipment should therefore include power units, which serve later as stand-by units.

In advanced countries, contracting firms with years of experience are available. In less developed ones, however, it is not so. Even in India, after many years of major construction work, it is difficult to find more than a dozen good construction firms. Hence construction of major projects is done by government departmental organizations, which have in consequence to be built up with talented men.

As no workshop facilities, unlike in advanced countries, will be available within a reasonable distance, it is necessary to build up a large workshop at each major work site. Repair and reconditioning sections should be particularly well-arranged.

Due to lack of machinery such as cranes and other mobile equipment, the closure operation in river works present considerable difficulties in less advanced countries. These have therefore to be planned with foresight, making provision for failure of any particular operation. It is a usual sight in India to see strenuous attempts being required to close a gap even when the flow is only 5 to 10 thousand cusecs.

In dewatering of foundations, it may be assumed that heavy dewatering pumps and well-point systems will not be available, and dewatering has to be done through the use of such heterogeneous pumping plants as would be available, and by making use of big suction wells, etc.

It will thus be observed that engineering works, wherever they may be located, though based essentially on the same technical principles of design and construction, in details of organization and execution call for different approaches and techniques suited to the state of development of technology, the economic conditions, indigenous materials, climate and other factors obtaining in the region.

Part II

Aspects of Organization of a Water Development Department; Training of Staff; International Co-operation

Effective Water Development Projects

Put to proper use rivers are veritable treasures. They are engines of destruction, if not properly controlled. Thus the river Jhelum with waters in excess of 30,000 cusecs, or the river Godavari in excess of 2.5 million cusecs, cause similar destruction and suffering. The occurrence of floods is frequent when the waterway of the river system gets restricted due to silting or other reasons. Thus the Kosi is notorious for destructive floods, for the river course swings from East to West. It has moved laterally as much as 80 miles in the last hundred years. Every year the monsoon onslaught is dreaded in the Kosi Valley. The cause for the lateral movement is the immense coarse silt load that the river brings down from the Himalayas and deposits capriciously on the Bihar plains. The river is called the River of Sorrow of India, just as the Yellow River is called the River of Sorrow in China. Another interesting example of a river with recurring floods in India is the Mahanadi. The reason here is different. Man encroached on the various branches of the river in the deltaic portion. He built embankments and prevented the spill of the river over the lands, which therefore remain lower than the river bed. The result is that the waterway to the sea is reduced unduly and frequent floods occur through breaching of embankments.

Countries and regions where people suffer most from floods, are naturally most anxious for flood control. Hence it is that when China got sovereignty over the mainland, the first task undertaken was to build flood control works on the Yangtze, Huai and Yellow rivers. On the Yangtze, a flood detention reservoir was constructed; on the Huai, a series of flood storage reservoirs were built and floods were controlled on the Yellow river through the construction of embankments and a huge silt detention reservoir at the Sanmen Gorge. In India, the first projects undertaken after attaining independence, in Bihar, Orissa and Bengal — regions subject to heavy flood havoc — were the Kosi, Hirakud and DVC, whose principal aim is to moderate the floods.

In the tropical climate, where rainfall occurs only for a few months, irrigation is most essential. Every farmer welcomes an irrigation project. Hence it is that India undertook a number of irrigation projects after 1947 (the year of Independence). Projects worth Rs. 1,700 crores have been undertaken, and Rs. 1,300 crores will have been spent by 1965. The irrigation potential has been increased from 22 million acres to 31 million acres now under major and medium irrigation schemes, the ultimate aim being to irrigate 100 million acres, in addition to 75 million acres under minor irrigation projects. Besides this the programme of irrigation projects will continue till all the dependable river flow is utilized. Out of 1,350 million acre ft. of waters in Indian rivers, it is estimated that a third can be put to beneficial use. Out of this, about 110 million acre ft. will be used by the projects undertaken till 1961. It is of interest that the most used up river in the world from the point of irrigation is the river Cauvery, 95 per cent of whose waters have been put to use. Irrigation projects in India are broadly considered under three headings:

a) Major — projects costing more than Rs. 5 crores.

b) Medium — projects costing below Rs. 5 crores, but above Rs. 1 million.

c) Minor — projects costing less than a million rupees.

The first two categories benefit large and extensive areas, assure protection in years of scarcity and can be designed to serve a multiplicity of purposes. Minor schemes require comparatively small outlays, yield quick results and can be constructed with local resources, but their serious limitation is that they fail in drought years when protection is needed most.

It is found that financial returns from irrigation projects are not great — generally not able to meet the interest charges. Levy of betterment charges and increase of water rates may help in improving the returns. Even so the direct returns from irrigation projects will not be high. Hence the financial return should not be the only criterion for assessing the overall benefits of a project, in view of the several indirect benefits such as extensive utilization of lands, increase in farm output, productivity and incomes, employment and stimulus for industries, trade and transport. In assigning priorities for irrigation projects, the main aim should be to undertake projects which are productive and yield maximum benefits with the least investment. As the country develops, other projects which serve scarcity areas and set right regional imbalances of development should be taken up.

One of the cheapest methods of diverting river flows for irrigating land is the construction of weirs, where possible. Commencing with the Grand Anicut across the Cauvery in the 10th Century, here are sixty weirs in operation in India diverting nearly 300,000 cusecs of water for agriculture.

Water transport provides the cheapest mode of conveyance and is specially suitable for less developed countries. It plays an important role in the north-east region of India where nearly one and a quarter million tons of traffic, between Assam and Calcutta, is carried by river. The backwaters in Kerala connect several minor ports and the major port of Cochin, serving a number of industries situated close to them. In the deltaic regions of Orissa, Godavari and Krishna, inland waterways provide an important means of communication. The Eastern Coastal Canal and the Buckingham Canal afford a useful interstate conveyance. The capacity of major ports in India has been increased from 20 million tons to 37 million tons in the first two Plans. A major port at Kandla has been constructed on the West Coast and an ancillary port is about to be taken for construction at Haldia.

Industrial uses of water are not very many in less developed countries, and the problem has not yet grown large, except in a few regions like the Damodar Valley in India. Here it happens that the valley has all the coal and other minerals and is the hub of great industrial activity. There is a great demand for water for industrial uses.

It is now realized that power is most essential for solving the unemployment problem and an all-round rise in the standard of living. In less developed countries, there is *great urge for a socialistic form of economy as the people feel that all their present suffering is due to capitalistic exploitation. Power is synonymous with Socialism.* This realization however has begun to develop only in the last few years, for even in India, with its vast awakening and close contacts with Western nations, importance of power was not realized during the First Plan period, between 1951 and 1956. Now injury to the growing economy by power famine is being felt more acutely than food famine.

India has therefore allotted nearly Rs. 1,100 crores during the current plan, 1961 to 1966, for power development, while during its first two plans it spent only Rs. 640 crores. Not only that, it is taking steps to double its installed capacity in the Fourth Plan. Though there are plentiful supplies of coal in India, these are concentrated only in a few localities and transport is a bottleneck. Cheap power can be produced through utilization of water resources. There are a large number of huge, economically exploitable possibilities in the country. It is estimated that these add up to about 40 million kilowatts. Of this, up to about two million kilowatts has been harnessed. Thus there are several hydro projects that have yet to be developed. Hydro projects so far exploited utilize heads up to 3,000 ft.

The development of rivers is eagerly sought for in all countries, more so in less developed countries. The emphasis on the type of project is dependent on the conditions prevailing in the region. It may be stated generally that irrigation projects are greatly welcomed in countries where the population is large, and food is insufficient. In countries, a little more advanced, where educated unemployed begin to predominate, power projects must be given priority.

Flood control projects are incorporated with irrigation or power projects. They are rarely taken up as individual projects solely for flood control.

Water Development Department

Scientific organization of Water Development Departments is of utmost importance specially in less developed countries, as on it depends the promptness, economical construction and success of river projects.

In India there is a Ministry of Irrigation and Power at the Centre, which integrates the plans and State proposals for major projects in the country. The Central Government advances loans to the States for construction of all such projects and hence exercises control over planning and designs and progress of the projects. It allots to the States scarce materials like cement, steel and foreign exchange for construction machinery and equipment. There is a good central designs organization under the Ministry which helps the States in planning and designs. Sometimes when a State is unable to undertake investigations and requests for assistance, the Central Organization undertakes such work.

It is the responsibility of the 16 States to plan, secure designs and construction of the works. Irrigation is a "transferred subject". That is a State can freely formulate its irrigation policy, except in regard to inter-state rivers. Power is, however, a "concurrent subject", and both the States and the Central Government have a joint responsibility for its development.

The Central Designs Organization is a combined one for power and irrigation, though there are two distinct wings manned by specialists in each branch. These are known as the "Water" and "Power" Wings. Similarly in the States there are different technical departments, one headed by Civil Engineers and the other by Electrical Engineers. Recently in order to accelerate the programme of construction of electrical works, power departments in States are now set up under semi-autonomous organizations known as State Electricity Boards.

At the centre, major and medium irrigation projects, i. e. projects costing more than one million rupees are looked after by the Ministry of Irrigation and Power. Minor irrigation, utilizing small tanks and wells come under the purview of the Ministry of Agriculture. There has been a persistent demand that all irrigation must be combined under one Ministry.

Power plants are now sought to be produced under a semi-Government organization known as the Heavy Electricals Limited. This is under the Ministry of Steel and Heavy Industries. Practically all the generators, turbines, motors, etc., that will be produced by this undertaking will be utilized by the Ministry of Irrigation and Power. Therefore opinion is growing that power plant industries and power generaton should all be under one Ministry.

India has another unique organization known as the Planning Commission. This body draws up the targets for the nation and plans out its resources. Its Chairman is the Prime Minister and membership consists of a few Union Ministers and others drawn from public life. There is a member who looks after Natural Resources. The Planning Commission has the final say in sanctioning projects and fixing targets for completion. It has appointed a Technical Advisory Committee which scrutinizes proposed projects before they are sanctioned. With increased development of power, it is being realized that it is more economical and desirable to have a Central Ministry responsible for the generation of power all over the country. The distribution may be done by the States. This step will become inevitable when an all-India grid comes into being. At the moment, regional grids connecting power systems of two or more contiguous States are being planned. The country will be divided into seven power zones, which will be eventually, it is contemplated, connected, with obvious advantages of an inter-connected power network. All common problems are discussed at annual seminars attended by Ministers and Chief Engineers of the States and the Centre.

Many of the rivers flow through many States of a country or even through many countries. Exploitation of such rivers raise controversies, which have to be resolved quickly. Otherwise the developmental works will be greatly delayed. Thus the conflicts regarding the Colorado between several States went on for years before the Colorado compact was arrived at. River Mekong is an example of a river passing through a number of countries — Vietnam, North and South, Cambodia, and Thailand. Under the auspices of ECAFE, a Mekong Committee has been working satisfactorily on drawing up plans for projects on the Mekong. In India many of the important rivers flow through more than one State and often conflicts arise between the concerned States. In most cases agreement is reached and works proceed quickly. Controversy regarding the Krishna is an example of persistent dispute in the same country. In India, to resolve water disputes, where they cannot be solved by mutual discussions, there is an Act passed by the Parliament known as the Inter-State Water Disputes Act. The method provided is arbitration by a person to be nominated by the Chief Justice of India. The best method, however, is encouraging the parties to come together and arrive at a solution acceptable to all.

In India there is another Act, known as River Boards Act. This is meant to coordinate the activities of several concerned States, prepare schemes, and draw up plans of regulation of inter-state rivers.

Indian administration of river projects is fairly sound and is able to meet the needs of the country. Nevertheless some changes are desired with a view to shortening the procedures of sanctions, meet the need for a fast tempo of work and accelerate the progress of the projects.

Training of Staff

In an underdeveloped country, there will be an absence of adequate technical staff and consultants, and major projects will present difficulties at all stages of planning, design, construction and development. *The gap in the state of technology between developed and underdeveloped countries is more glaring and consequential than the inequality of wealth.* While the topmost senior engineers may have to be borrowed from other countries for some period, it is possible to draw up a training programme and prepare the young engineers of the country to fill in the other roles. This is what has been attempted in India, though engineering education was started a century ago and there are fairly a large number of well-equipped engineers in the country. For the Damodar Valley Authority an American engineer was employed; similarly for the Kandla Port Project, the Chief Engineer was a German engineer; for Bhakra the Construction Plant Adviser was an American. But, by and large, these foreigners have been few and the local element itself could supply the top engineers also.

The problem of training young engineers in the different fields of engineering, to give them a start on specialization, is a difficult one. A careful list of requirements, both immediate and long term, has to be prepared and selection of the best available men made. Places of training have to be found in the advanced countries and the selected men sent in for periods of one to three years. For senior engineers, it is a practice in India to send them on observational tours for four months. This does not constitute, however, proper training. Prior to sending the young engineers for training, an orientation course, giving preliminary technical knowledge on the subject of training and a fairly good knowledge of the language of the country to which they are being sent, should be given. The number so sent will naturally be few due to limitations of finance. These men on their return should be engaged on the same type of work for which they are trained so that they can develop into specialists and train other men in course of time. Some intense training programmes have been set up in the National Laboratories, the Atomic Energy Commission and the Ministry of Irrigation and Power within the country itself. But these have not been as successful as expected.

Apart from designing and construction engineers, special training will be necessary for creating a cadre of most useful class of specialist workers like grouting men, erectors of power plants, operators of construction and power plant, etc. The services of these men can be used on any project throughout the country. Without organized effort, these classes of workers cannot be found. The defect in Indian management of projects is that for these specialized jobs, they do not have the requisite number of men. Continual dependence on foreign talent for these works is costly, as the presence of experts will be required only off and on at intervals.

Besides these specialized classes, nearly ¾ million craftsmen of engineering trades are required even for the Third Plan. Several industries as well as establishments under Railways, Posts and Telegraphs, Defence, etc., have their own training programmes. For the rest, facilities are being provided in institutional training centres maintained by State Governments in collaboration with the Ministry of Labour and Employment. It is proposed to double the number of such institutes in the Third Plan, with an intake potential of 100,000. The apprenticeship training scheme, which was to be implemented by industry on a voluntary basis with a measure of support from Government did not make much progress during the Second Plan. An Act was recently passed, placing apprenticeship on a compulsory basis.

Training of technical staff in all cadres needed for the development of a country is a most essential detail to which utmost attention has to be paid to ensure achievement of a country's plans.

International Co-operation

In the field of river valley projects, there are excellent opportunities for advanced countries to come to the aid of less developed countries. Poverty and low standard of living are a blemish on enlightened humanity. They must be banished wherever they exist. The explosive increase of population indicates the necessity for speedily setting right the prevailing imbalance and help the people in lees advanced countries stand on their own legs.

The basic help that can be rendered to less developed countries is in respect of water projects. Co-operation can be extended by providing financial and technical assistance. To be of effective use, the technical assistance must be such that it will not only help in various phases of the project but also produce out of the citizens of the country men who can replace them. This last is of inestimable value and will be gratefully remembered for all time. Financial assistance can include supply of scarce construction materials and equipment. Since 1951, India received nearly Rs. 2,600 crores by way of financial assistance from various countries. The assistance was in the form of loans and grants. These amounts were largely employed for getting machinery and a sizeable portion on the purchase of food.

In a less developed country, by tightening in other fields and concentrating solely on water projects and the associated ancillary industries such as cement and steel, requirements of financial assistance required in the early period can be reduced. But as development takes place, and before the less developed countries attain a state of self-sufficiency, the foreign assistance required will increase. For example in Third Plan, in India, the foreign exchange requirement is estimated at Rs. 2,200 crores as against the requirement of Rs. 1,200 crores in First and Second Plans.

The cumulative urges, aspirations and efforts of today's backward countries, it will be seen, promise to make them the forward nations of tomorrow. The outstanding examples of such transformation in this very century are Japan and the U. S. S. R. Before the close of the century, there can be little doubt, several others will march forward to their ranks. In their striving and in their progress, the more advanced countries can lend a powerful hand. It will be a gracious act for which the less developed nations of today will be grateful. It will be an act towards the one world, towards the familiy of nations, for the attainment of which all men of goodwill, all people of foresight and culture are working with faith and hope.

Conversion Table

1 foot	30.48 cms
1 cusec	0.0283 cubic metres/sec
1 acre	0.4047 hectares
1 rupee	0.877 D. M.
1 lakh	100,000
1 crore	10 million

References

1. Symposium on Spillway — Capacity of Dams. C.B.I.P. publication 65.
2. Water Resources Vo. IV. Proceedings of the United Nations Scientific Conference on the Conservation and Utilisation of Resources. Appraisal of Water Resources: Analysis and Utilisation of data, forecasting water yield, flood runoff, flood frequency power potential.
3. *Khosla*, Shri A. N.: Chairman, CWING, GOI, New Delhi.
4. *Strange*, Sir William Lumisden: Indian Storage reservoirs with earthen dams.
5. Relative place of masonry and concrete in dam construction in India — Third Engineers Seminar.
6. Report on Chemical Studies of Surkhi R 12/51. Concrete Research Laboratory. Annual Report 1951.
7. Bhakra Dam Repair Safe for monsoon rains. 58 Apr. 21, 1960 Engineering News Record.
8. *Nath*, B.: Depressing subsoil water table for laying foundation raft of Sarda H. E. Power Station, ICJ. 1950, Page 179.
9. *Rao*, K. L.: Engineering Difficulties in River Valley Projects. September 1953, Institution of Engineers (India).

10. *Rao*, K. L.: Engineering Problems in Recent River Valley Projects in India — Institution of Civil Engineers, September, 1958.
11. Report Koyna Hydro Electric Project 1950.
12. Report Kundah Hydro Electric Project 1953.
13. Hand Book of Irrigation and Power Data. Publication of Central Board of Irrigation & Power, New Delhi.
14. Bhagirath Publications:
    (1) Bhagirath — Eight Anniversary Number July, 1962.
    (2) Bhagirath January 1963 — Issue.
    (3) Bhagirath Monograph — All about Chambal Valley Development.
    (4) Bhagirath Monograph — All about Rihand.
    (5) March of Irrigation & Power since Independence.
    (6) Chambal Valley Development.
    (7) Flood Control in India.
    (8) Bhagirath Pamphlet No. 1.
    (9) Bhagirath Pamphlet No. 2.
    (10) Bhagirath Pamphlet No. 3.
    (11) Tungabhadra Project.
    (12) Second Five Year Plan: Irrigation & Power.
    (13) Mayurakshi Project.
    (14) Major Water and Power Projects of India.
15. Third Five Year Plan of Government of India — Planing Commission.
16. *Tinbergen*, Jan: The design of development. The John's Hopkins Press Baltimore.
17. *Rao*, K. L.: Structural failures in weirs & dams. Journal of the Institution of Engineers (India). Vol. XL No. 12, August, 1960.
18. *Terzaghi*, Karl: Report: On design of coffer dams and on excavation conditions at the site of the proposed Ramapadasagar Dam Appendix I — Specification schedule & drgs. of Ramapadasagar Dam and power plant.

VI. Erosion et Transport des Sediments

par L. J. Tison

Introduction

Les questions relatives à l'érosion et au transport des matériaux solides furent longtemps, non pas négligées, mais en fait difficilement abordables, même dans les pays évolués.

Sans doute, il y eut les recherches de *Du Boys*, il y a plus d'un siècle sur les transports par charriage. Il y eut celles de *Fargue* sur la morphologie des rivières. Il y eut aussi *Gérardon* en France, *Franzius* en Allemagne, les corrections et améliorations du Rhin basées sur le mouvement des sédiments. Toutefois, il semble bien que les laboratoires d'hydraulique furent à l'origine des recherches fondamentales sur ces questions. La nécessité de se rendre compte de la validité des lois de similitude pour ces problèmes conduisit alors à l'obligation de mesures directes, sur les cours d'eau, des quantités de sédiments transportés ainsi qu'à des observations systématiques des variations du lit, à l'étude de sa morphologie. Nous ne désirons nullement exposer en détail les résultats de ces recherches qui en fait ne datent que d'une cinquantaine d'années, recherches qui subirent d'ailleurs des fluctuations d'intensité assez notables. En rappelant ces quelques éléments de base, notre but est simplement de montrer combien cette science de l'érosion et du transport des sédiments est jeune, combien les solutions qu'elle avance manquent encore parfois de précision, combien de recherches sont encore nécessaires pour arriver à un développement présentant quelque maturité, même en pays dits évolués.

Est-ce à dire que, dans ces conditions, il y aura peu de choses spéciales à dire de ces problèmes pour les pays en voie de développement et que leur étude et leur solution différeront peu de celles envisagées dans nos régions? Nous estimons au contraire que, par bien des aspects, ces questions méritent d'être étudiées spécialement dans les pays en transformation, comme nous allons le voir.

Quelques aspects de ces questions dans les régions en voie de transformation

Leurs plus grandes caractéristiques sont probablement l'énormité des problèmes, les données insuffisantes dont on dispose, allant de pair avec la nécessité de réalisations rapides et avec des moyens limités.

L'énormité des problèmes

Sans doute, cet aspect n'est pas tout à fait particulier aux problèmes qui nous occupent; toute l'hydrologie de ces régions est marquée de la même caractéristique.

Les régions tropicales et équatoriales par exemple sont souvent soumises non seulement à des précipitations totales considérables, mais à des concentrations exceptionnelles dans l'espace et dans le temps. Même des régions arides ou au moins semi-arides donnent lieu à des concentrations de cette espèce, courtes sans doute mais terribles dans leurs effets. Mais encore faut-il cependant observer que les phénomènes d'érosion et par suite de transport sont, toutes choses égales, plus intenses dans les contrées dont il est ici question du fait, non seulement des conditions hydrologiques proprement dites, mais aussi du fait d'une grande érodibilité des sols et du manque ou de la disparition de leur protection. La morphologie des cours d'eau y présente d'autre part des problèmes dus à l'intensité des phénomènes qui se déroulent et s'y sont déroulés librement. On peut donc dire que, de tout le domaine de l'hydrologie, c'est dans les questions qui nous occupent qu'on rencontre les plus vastes, les plus intenses de toutes les actions. On pourrait presque dire que les pays évolués tous situés dans les régions tempérées y sont soumis à des conditions hydrologiques elles-mêmes tempérées, modérées, alors que les autres contrées se caractérisent par des conditions excessives.

Dans nos régions à vieille civilisation, rares sont celles qui disposent de données, ne disons pas suffisantes, mais permettant simplement de se faire une idée générale des caractéristiques hydrologiques.

Que dire des nations neuves? On y est allé au plus pressé, on a commencé par les précipitations, puis l'écoulement liquide, mais où s'est on arrêté aux mouvements solides? Dans les tout derniers temps, les questions de l'érosion des sols y ont quelque peu retenu l'attention, mais en fait, c'est la pénurie quasi complète pour les données qui nous intéressent.

D'autre part, c'est dans ces régions qu'il faut réaliser ponts, barrages, épis, digues, etc. au plus vite, pour établir des communications, produire de l'énergie, protéger contre les inondations, etc. Pour résoudre ces problèmes, dont ce qui est relatif à l'érosion, au transport des matériaux et à leur sédimentation est aussi important, si pas plus que les données se rapportant aux débits liquides. Et on ajoutera que les fonds disponibles sont toujours si limités qu'il faudra imaginer des solutions quasi de fortune et en tout cas exigeant une surveillance et des observations que les modifications politiques fréquentes font souvent oublier.

Erosion Continentale (Land-Erosion)

1. *La Source des sédiments*

La source des sédiments, en dehors des zones industrielles, est l'érosion des sols. Sans être spécifique aux régions neuves, ce phénomène s'y exerce cependant souvent avec une intensité particulière. L'étude de cette érosion et surtout celle des remèdes à y apporter ne sont sans doute pas du domaine purement hydrologique, mais elles sont cependant liées au ruissellement, à l'infiltration, à l'écoulement des eaux souterraines, etc., si bien que nous ne pouvions laisser ce point complètement dans l'ombre.

On a suffisamment mis en lumière l'importance de cette érosion, mais les quelques chiffres suivants donneront un aperçu rapide de quelques valeurs mesurées.

Le Mississipi, aux environs de 1945, déversait en moyenne annuellement à la mer 700 millions de tonnes de sédiments (soit environ 200 tonnes par km^2 de bassin) sur les 1.250 millions que toutes les rivières des U. S. A. conduisaient à l'Océan. Mais la perte de sol par l'érosion de l'ensemble du pays était de 4.000 millions de tonnes, la différence s'arrêtant dans les lits, les plaines d'inondation, les réservoirs, etc. Le Colorado au Grand Cañyon emporte environ 750 tonnes par km^2 de bassin versant (1).

On peut rapprocher de ces chiffres quelques rares indications sur le fleuve Congo qui semble ne jeter à l'Atlantique que 38 millions de tonnes par an, dont plus de 90 % comme matières en suspension (2).

Par contre, le Nil amenait à l'amont du réservoir d'Assouan 136 millions de tonnes de matières en suspension du 14 juillet au 22 novembre 1938 et il ressortait du réservoir 129 millions de tonnes durant la même période. Il est vrai que pendant le reste de l'année, le débit solide est bien moins important (3).

A noter que tant pour le Nil que pour le Congo la décantation dans les lacs et régions marécageuses de leur bassin supérieur réduisent fortement la quantité de matériaux transportés.

Ces chiffres quoique se rapprochant de ceux du Mississipi, leur sont encore inférieurs.

Par contre, pour les cours d'eau algériens et tunisiens (avec des bassins bien moins étendus), on trouve des chiffres qui dépassent parfois 100 tonnes par km^2, même par des étendues de bassin, de l'ordre de 20.000 km^2 (4).

On a d'ailleurs essayé de se rendre compte de la répartition de l'érosion dans le monde, sur des bases à la fois raisonnées et statistiques, et c'est ainsi qu'on a proposé la formule:

$$\log \text{D. S.} = 2{,}65 \log \frac{p^2}{P} + 0{,}46 \log \frac{H^2}{S} - 1{,}56$$

D. S. dégradation spécifique exprimée en tonnes entrainées par km^2 de bassin;

p est la hauteur de précipation du mois le plus arrosé et

P est la hauteur de précipation totale.

H est la hauteur moyenne du bassin exprimée en mètres, et

S son étendue en km^2.

Cette formule tient compte des résultats de mesures faites sur 200 cours d'eau répartis dans le monde entier (5).

Cette formule ne peut évidemment être acceptée qu'en faisant des réserves, par suite de l'insuffisance en nombre et en qualité des mesures de débit solide qui ont servi à l'établir. Elle conduirait à la conclusion qu'une ablation moyenne de 1 m demanderait:

14.660 années en Europe

5.128 années en Australie

2.857 années pour l'Amérique du Nord et Centrale

2.300 années pour l'Asie

2.000 années pour l'Amérique du Sud et l'Afrique.

Ces chiffres montrent le bien-fondé de nos considérations générales sur l'importance relative de l'érosion en Afrique, en Amérique du Sud, en Asie et en Amérique Centrale (qui intervient notablement pour réduire le chiffre de l'Amérique du Nord indiqué ci-dessus). A priori, cette formule semble donner une limite supérieure de l'érosion, correspondant sans doute aux valeurs actuelles, lesquelles sont influencées dans le sens d'une aggravation de l'érosion du fait de l'action de l'homme.

2. *Mesures de l'érosion*

Les mesures directes de l'érosion elle-même ont été faites depuis une vingtaine d'années en se servant de parcelles expérimentales. Pour ces parcelles expérimentales, on mesure les pluies, le débit superficiel, le débit souterrain, ainsi que le volume de matériaux entraînés. Le choix des parcelles est fait de façon à pouvoir s'assurer, à l'aide de quelques précautions, qu'aucune eau extérieure ne pénètre dans la parcelle et que, d'autre part, aucune eau tombant sur cette parcelle n'échappe aux mesures. A côté de ces mesures sur parcelles d'étendues variables, on a aussi fait l'étude de parcelles d'étendue réduite sur lesquelles la pluie était simulée à l'aide d'appareils (voir Comptes-Rendus du Colloque de Bari) (6).

D'autre part, la mesure des transports solides dans les cours d'eau a donné naissance à diverses classes d'appareils. Il ne peut être question dans un exposé comme le nôtre de présenter ces divers points en détail. Tant pour les parcelles expérimentales que pour les appareils, nous renvoyons à la littérature.

3. *Lutte contre l'érosion*

Il en est de même pour les mesures préventives et de lutte contre l'érosion. Elles relèvent d'ailleurs beaucoup plus du domaine du pédologue et de l'agronome que de celui de l'hydrologue et de l'ingénieur.

Il faut d'ailleurs s'efforcer de réduire le volume des sédiments arrivant aux réservoirs. On a, à ce propos, proposé certaines techniques qui ont donné de bons résultats dans l'Amérique de l'Ouest et qui, dans l'ensemble, paraissent donc pouvoir s'appliquer aux pays neufs (7).

a) Utiliser des bassins de décantation secondaires en amont du réservoir.

b) Établir des écrans denses de végétation au travers desquels les eaux chargées de sédiments devront passer. Le tamaris s'est spécialement montré effectif à cet usage. On n'oubliera pas qu'il consomme beaucoup d'eau.

c) Quand possible, by-passer une partie du débit alimentant le réservoir.

La manœuvre raisonnée des dispositifs d'évacuation de crue peut aussi permettre une évacuation intéressante des sédiments amenés au réservoir: c'est ainsi qu'il y a avantage à évacuer le plus rapidement possible les eaux fortement chargées. D'autre part, on n'oubliera pas que ces eaux chargées se meuvent dans les lacs sous forme de «courants de densité». Une étude de ceux-ci, par modèles réduits comme on l'a signalé, peut conduire à donner aux vannes d'évacuation des emplacements priviligés.

Au sujet des pays en voie de développement et surtout des régions arides, signalons encore que d'après *Langbein* et *Schumm*, les productions les plus élevées de sédiments ont pour origine des régions recevant 380 mm. de précipitations. Au-dessous de ce chiffre, la production de sédiments décroît quand les précipitations diminuent et au-dessus de 380 mm., la végétation tend à diminuer la production des sédiments qui décroissent donc avec des précipitations croissantes. La nature du sol et du relief doivent cependant aussi intervenir.

Erosion et Transport Generaux

Il nous a paru indiqué de traiter à part les multiples problèmes d'érosion due à des circonstances locales.

Il ne sera question dans ce chapitre 3 que de déplacement des matériaux non influencé par ces conditions locales.

On est loin déjà des premières études sur l'érosion où l'on s'efforçait simplement de lier l'érosion à la vitesse moyenne. Toutefois, il ne rentre pas dans le cadre de cette étude d'aborder les considérations théoriques émises en se basant sur la notion de tension d'entraînement et surtout pour relier la théorie du mouvement des matériaux solides avec les résultats des théories de *Prandtl* et *von Karman* sur le mouvement turbulent. L'exposé des résultats successivement établis par *C. White, Shields, Kalinske* et *Lane, Einstein* et bien d'autres dans ce domaine, ainsi que le rappel des nombreuses formules empiriques du transport solide basées en général sur la vieille formule de *Du Boys* nous conduiraient déjà très loin, pour le seul charriage sur le fond.

Disons cependant que de nombreuses vérifications sur des cours d'eau naturels des formules de *Meyer-Peter, d'Einstein* ont donné de bons résultats.

La question du débit des matières en suspension a elle aussi, progressé très rapidement. Ces développements se sont basés sur la relation de la diffusion, introduite dans la littérature relative aux sédiments par *O'Brien*, sous la forme (12):

$$c \cdot w = -\varepsilon \frac{dc}{dz} \qquad \text{III,1}$$

c était la concentration de matières en suspension,

w est la vitesse de chute de ces sédiments et

z la hauteur.

Hunter Rouse a pu développer cette théorie et arriva à la relation:

$$\frac{c}{c_0} = \left(\frac{z-a}{h-a}\right)^{2,5\frac{w}{\sqrt{\tau/\rho}}} \qquad \text{III,2}$$

h est la hauteur totale de l'eau

c est la concentration à un niveau de référence a

z est la hauteur du point de concentration c et

τ est la tension d'entraînement tandis que

ϱ est la densité de l'eau

Lane et *Kalinske* ont pu déduire de cette loi de variation de c, une expression du débit des matériaux de suspension.

On remarquera toutefois qu'il reste beaucoup à faire dans le domaine du transport des matériaux tant sur le fond que suspendu, du fait que les lits des rivières ne sont, en général, pas uniformes d'où il résulte une variation du taux de transport de section en section, du fait aussi de la non-permanence du mouvement qui amène une variation de ce même taux avec le temps.

Dimensions à donner aux canaux avec débits solides (1)

La solution à ce problème est évidemment une question d'équilibre pour qu'il n'y ait ni érosion, ni dépôt.

En partant des formules de transport du type *Du Boys,* on peut arriver à la formule suivante de la vitesse d'équilibre (pour laquelle, il n'y a ni érosion, ni dépôt): (en pieds par seconde)

$$V = 0,2\left(\frac{q_s}{q}\right)^{1/3} \frac{d_m^{\ 1/4}}{n^{4/3}(1-{}^{i_0}/_{i})^{1/3}}\, h^{5/9} \qquad \text{III,3}$$

q_s est le débit solide correspondant au débit liquide q. Quant à d_m, c'est le diamètre moyen en mm. des grains constituant les sédiments tandis que n est le coefficient de *Manning.*

i_0 est la pente pour laquelle le mouvement solide commence. Cette formule est à rapprocher de la formule de *Kennedy* souvent utilisée sans discernement (1).

Mais pour résoudre les problèmes relatifs aux canaux, on peut se baser sur les relations suivantes, pour un canal de largeur B à la surface, de profondeur moyenne h_m:

$$Q = \frac{1,49}{n} B \cdot h_m \cdot R^{2/3}\, i^{1/2} \qquad \text{III,4}$$

(c'est la formule de *Manning* R étant le rayon hydraulique).

$$Q_s = \frac{0{,}17}{d_m} \gamma^2 B\, h_m^{\,2}\, i^2 \left(1 - \frac{i_o}{i}\right) \qquad \text{III,5}$$

Q et Q_s sont respectivement les débits liquide et solide du canal, γ étant le poids spécifique de l'eau (unités fondamentales: pied, livres, seconde).

D'autre part, d'après *Straub:*

$$i_o = 0{,}00025 \left(\frac{d_m + 0{,}8}{h_m}\right) \qquad \text{III,6}$$

d_m seul est en mm.

Si on veut par exemple créer un canal avec eau claire, dans un terrain de sédiments, en lui donnant la pente aussi grande que possible, pour ne pas allonger son tracé, on disposera de l'équation (III, 6) qui donnera le produit $i_o\, h_m$ correspondant au d_m du terrain. L'équation (III, 4) permettra alors de trouver les dimensions du canal pour le débit Q à évacuer et pour la forme de section généralement admise dans la région (1).

Si le canal est alimenté par une eau chargée d'alluvions, on déterminera par mesures sur place le rapport Q_s/Q de l'eau à utiliser et l'emploi des 3 équations ci-dessus permettra de résoudre le problème (1).

A remarquer d'ailleurs qu'avec le temps, les parois du canal par colmatage et cimentage deviennent en général plus cohérentes et de ce fait plus résistantes à l'érosion. On peut utiliser cette propriété en utilisant le canal neuf pour des débits limités par la résistance des parois, comme il est dit ci-dessus et en augmentant graduellement le débit quand la cohésion améliore la résistance.

Si au contraire, on veut créer un canal à pente aussi réduite que possible (canal d'irrigation, de transport de force), le problème ne présente certaines conditions que si l'eau est chargée de sédiments. Si la charge solide à évacuer est imposée, le problème se résoud à l'aide des 3 équations comme ci-dessus.

Pour les aménagements de rivières, le problème se complique du fait de la variabilité du débit et aussi des conditions apportées par les coudes par exemple.

Les hydrauliciens allemands et autrichiens ont tourné la première difficulté en faisant appel à la courbe des fréquences qui jointe à la relation donnant Q_s permet d'introduire la notion de «bettbildend» débit.

Le caractère divaguant des cours d'eau des pays neufs a souvent causé de grandes difficultés. La fixation du lit à l'aide de digues et mieux d'épis devra être réalisée, les dimensions du lit ainsi constitué étant déterminées en s'aidant des résultats ci-dessus.

Nous avons eu connaissance de pareil problème au Pakistan: une centrale thermique avait installé une prise d'eau à un fleuve dont les divagations rendaient la prise très précaire: le fleuve risquant tantôt de s'écarter de la tête de la prise, tantôt de la mettre en danger par érosion. La solution définitive ne peut se trouver que dans la fixation du lit.

Les recherches vers les phénomènes dont nous venons de parler et particulièrement dans le cas spécial des zones arides se sont développées dans les dernières années. Il ne peut encore une fois être question d'entrer dans leurs détails au cours de cet exposé, mais on pourra se référer aux études de *Langbein*, de *Léopold* et *Maddock*, de *Leopold* et *Miller*, de *Wolman* et *Leopold* et d'autres qui ont poussé très loin l'étude des relations existant entre le débit, la largeur, la profondeur moyenne, la vitesse moyenne des dimensions des matériaux transportés; certains auteurs (15).

L'étude de la morphologie des plaines d'inondation a également permis d'aborder des problèmes du plus grand intérêt et de les faire avancer sérieusement, si pas de les résoudre complètement. C'est ainsi que des progrès notables ont pu être faits dans la question des méandres et notamment du rapport de leur longueur d'onde à leur largeur, à leur débit et à leur pente.

L'étude des rivières avec chenaux à entrelacs dont il a été dit un mot plus haut a pu aussi être abordée. Répétons cependant que toutes ces recherches devraient être continuées et développées.

Models Réduits

La complication des problèmes posés par l'érosion et le transport des sédiments a souvent poussé à leur étude à l'aide de modèles réduits. Des solutions heureuses ont souvent été trouvées de cette façon. Toutefois, on observera que l'utilisation de ces modèles demande une formation et une expérience très poussées. Les lois de similitude sont rarement applicables en stricte exactitude; bien souvent, on ne peut en effet utiliser des matériaux à l'échelle de ceux de la nature, les réductions de profondeur amènent des turbulences elles-mêmes réduites, les répartitions des vitesses satisfont rarement dans le modèle à celles de la nature, la cohésion n'intervient pas de la même façon, etc. etc. D'autre part, les distorsions d'échelles souvent introduites en pareil cas, amènent de nouveaux troubles. La réalisation à l'échelle du modèle d'érosions et de transports répondant à ce que l'on constate dans des situations naturelles existantes, permet souvent de se faire une idée de la valeur du choix des échelles, des matériaux pour des situations que l'on veut modifier par certains travaux. Il n'en reste pas moins vrai que ces essais présentent une certaine difficulté et nous aurions quelque appréhension de les voir utiliser par un personnel n'ayant pas une grande expérience.

D'autre part, certaines études de base ne se rapportant pas à des cas concrets ont souvent été faites en laboratoire pour trouver par exemple des formules de vitesse, critiqua d'érosion, de débit solide, de suspensions, de méandres, de divagation, etc. etc. Là aussi une grande experience est de rigueur.

Conclusions

a) Disons encore une fois que l'exposé qui précède a dû se borner à une revue des problèmes plutôt qu'à indiquer toujours leur solution. Nous l'avons fait cependant pour quelques questions dont il est moins souvent question.

b) L'importance de ces problèmes pour les pays neufs n'a pu être montrée que par quelques-uns des exemples que nous avons rencontrés: la multiplication de pareils exemples aurait été aisée. On remarquera cependant qu'il résulte de cet exposé que l'érosion des sols est un phénomène dont souffrent particulièrement de nombreux pays neufs. Or, tous les problèmes de transport de matériaux solides sont influencée par la quantité érodée; tous les problèmes envisagés sont donc sinon particuliers aux zones neuves, du moins particulièrement importants dans ces régions.

c) La difficulté de la solution des ces problèmes est augmentée, d'une part par le fait que peu de chose a été fait jusqu'à présent, alors que les pays développés ont disposé de siècles pour apporter remède à la situation, souvent empiriquement nous le voulons bien: On pourrait presque dire que tout est à faire dans les régions qui nous préoccupent et souvent elles ne disposent que d'un personnel peu nombreux et insuffisamment formé.

   Ces considérations rapides, permettent de se rendre compte de l'intérêt et de l'importance de l'intervention des pays développés dans ce domaine.

References

1. *Brown*, C.: Sédiment transportation dans Engineering Hydraulics de Hunter Rouse. J. Wiley and Sons, 1950.
2. *Spronck*, R.: Mesures hydrografiques effectuées dans la région divagante du bief maritime du fleuve Congo. Inst. Royal Colonial Belge — Mémoires Collection in 8e — Tome III, Fasc. 1, 1941.
3. *Simaika*, Y. M.: The Suspended Matter in the Nile. Physical Dept. Paper no. 40. Ministry of Public Works Egypt.
4. *Tixeront*, J.: Débit solide des cours d'eau en Algérie et en Tunisie.
5. *Fournier*, F.: Débit solide des cours d'eau. Essai d'estimation de la perte en terre subie par l'ensemble du globe terrestre.
6. Association Internationale d'Hydrologie scientifique — Colloque de Bari 1962 — Diverses études.
7. *Du Boys*, P.: Le Rhône et les rivières à lit affouillable. Annales des Ponts et Chaussées. Série 5. Vol. 18, 1879.
8. *Lane*, E. W. et *Kalinske*, A. A.: The Relation of Suspended to Bed Materials in Rivers — Trans. A.G.U. Vol. 20 — 1939.,
9. *Shields*, A.: Anwendung der Ähnlichkeitsmechanik und der Turbulenzforschung auf die Geschiebebewegung — Mitt. des Preuß. Versuchsamt f. Wasserbau und Schiffbau, Berlin, H. 26, 1936.
10. *Meyer*, Peter E., *Favre*, H., et *Einstein*, H. A.: Neue Versuchsresultate über den Geschiebebetrieb. Schweiz. Bauzeitung, 1934.
11. *Einstein*, H. A.: Formulas for the Transportation of Bed Load — Trans. A.S.C.E. Vol. 107, 1942.
12. *O'Brien*, M. P.: Review of the Theory of Turbulent Flow and its Relations to Sediment Transportation. Trans A.G.U. Vol. 14, 1933.
13. *Tison*, L. J.: Erosion autour de piles de ponts en rivière. Annales des Travaux Publics de Belgique, 1940.
14. *Tison*, L. J.: Erosion autour d'obstacles en saillie sur les rives. Congrès des Sciences Liège, 1939.
15. *Wolman*, M. Gordon, and *Leopold*, *L.*: River Floods Plains: some observations on their formation. Geol. Survey Professional Paper 282. C. Washington, 1957.
16. *Leopold*, L., and *Woleman*, *G.*: River Channel Patterns: Braided, Meandering and Straight, Id. 282-B.
17. *Leopold*, L., and *Miller*, *J.* P.: Ephemeral streams, hydraulic factors and their relation for the drainage net: Id. 282-A.
18. *Leopold*, L., and *Maddock*, T.: Hydraulic Geometry of stream channels and some physiographic implication. Id. no. 252.
19. *Schaffernak*, F.: Grundriß der Flußmorphologie und des Flußbaues. Wien, Springer, 1950.
20. *Vanoni*, V. A.: Transportation of suspended sediment by water. Am. Assoc. Soc. Civ. Eng. Trans. no. 111.
21. *Einstein*, H. A.: The bed-load function for sediment transportation in open channels flows. U.S. Dept. Agr. Tech. Bull 1026, 1950.
22. *Langbein*, W.: Hydrologie des Eaux superficielles. UNESCO. Colloque de Paris. Colloque no. 1, 1960.

23. *Inglis,* Sir C.: The Behavior and Control of Rivers and Canals. Central Water-power, Irrigation, and Navigation. Res. Sta. Poona Res. Publ. 13.

24. *Tison,* L. J.: Au sujet de certaines dispostions permettant de réduire les quantités de matières solides entraînées par un système à surface libre. Deuxièmes journées de l'Hydraulique. Grenoble, 1952.

25. *Tison* jr., G.: Essais sur modèle réduit pour la prise d'eau sur la Lwiro (Congo Belge). Comptes-Rendus de la Septième Assemblée Générale de l'Association Internationale de Recherches Hydraulique. Lisbonne, 1957.

VII. Hydrologic Investigations in the Absence of Long Range Records

by A. Volker

Hydrologic Methods with Special Regard to Insufficient Data

One can not expect a hydrologic design to be made in the absence of any data. *Hydrology in the absence of adequate data is not the* equivalent of hydrology based on long range records. The subject should be formulated in a different way. Due consideration should be given to the practical purpose of the investigations, i. e. the short-term and the long-term needs. In the short-term needs all depends on the stage of the project work: the tentative design, the feasibility study, the preliminary design or avant-project, the master-project and the operation. The hydrologic methods should be chosen accordingly. They all come from one and the same way of thinking.

This thesis will be worked out in the following sections. For reasons of convenience the subject will be divided into surface water hydrology and ground-water hydrology.

1. Surface Water Hydrology

The best compilation on hydrologic methods when records are inadequate has been given in Flood Control Series no. 15 of the Economic Commission for Asia and the Far East (ECAFE — Bangkok), published in 1960 (lit 1).

Methods

Langbein suggests a minimum network plan for rain and streamflow gauging stations as a function of density of population. This relation is based on a comparison of the number of gauging stations in the various countries of the world. Reference can also be made to a publication of W. M. O. (lit 3).

The construction of isohyetal maps in mountainous areas where the number of rain gauging stations is not sufficient can be improved by applying the relationship between precipitation and altitude as derived from the records of the existing stations. A careful study of vegetation associations permits an approximate estimate of seasonal precipitation in semi-arid zones provided that there are a few precipitation stations where the vegetation may be calibrated.

Regarding the problem of determining the seasonal and annual yields of a river basin when records for only a few years are available, both Langbein and Kalinin refer to commonly known methods. These are based on establishing the relation between rainfall and yield for those years for which data are available and applying this relationship to other years when only rainfall is known.

The American and Russian authors differ in the methods for estimating the magnitude of floods when no adequate records are available.

The American author refers to the relation between flood peak and drainage area, the relation between the peaks of the unit hydrograph (expressed in discharge per unit of area and per unit depth of run off) and simple physical basin characteristics such as length of slope of the water course and the relations between storm rainfall and run-off using antecedent conditions as an index.

The two Russian hydrologists mention a method which is based on a combination of the rational method and the isochrone method. To estimate the travel time of the flood water a semi-empirical formula is given. There are some coefficients to be assumed and the authors state that the suitability of the formulae and the value of the coefficients must be checked when applying these to other regions. The impression is obtained that the methods are more suitable for comparatively small basins than for larger ones for which they may yield too high figures.

Flood forecasting by flood routing is dealt with by Vashnov. His method is essentially the same as those discussed in the (American) textbooks on hydrology. An empirical relation is derived between the storage in a river reach and the outflow and inflow of that reach. Outflow and inflow are given equal weights. In this respect the American methods of flood routing with different weights have a wider range of applicability.

Synthetic Hydrographs

It may be useful to mention the good results obtained with a method based on the principles of the unit hydrograph but requiring less complete data for computing flood hydrographs. The method was originally proposed by *Clark* (U. S. A.) and further elaborated by *Tatsugami* (Japan).

It is essentially based on accounting separately for the two elements which modify excess rainfall into discharge: travel time and storage. This can be done by routing excess rainfall through a hypothetical reservoir near the outlet with storage characteristics equivalent to those of the given river basin. The inflow to the reservoir is caused by excess rainfall distributed according to a time-area diagram with a base width equal to the maximum travel time.

The storage characteristics are derived from the descending limb of the hydrograph after the point of contra flexure when all further discharge (Q) at the outlet is derived from channel storage (S). From this recession follows the value of K in:

$$S = K Q$$

K is constant for a given catchment area.

The time difference between the cessation of rainfall and the time of occurrence of the point of contra-flexure is considered as a measure of the maximum travel time of the flood wave. This time difference is used as base width of a time area diagram showing the size of the subareas between the isochrones. The time area diagram is converted into a time-inflow diagram by applying an instantaneous rainfall over the river basin. This time-inflow diagram is then routed through the reservoir $S = K Q$, yielding the required hydrograph as outflow from that reservoir.

The only data required for computing a hydrograph is:

a) A topographical map;

b) The time lag T_l between cessation of rainfall and the point of contra-flexure;

c) The rate of decrease of discharges during the recession.

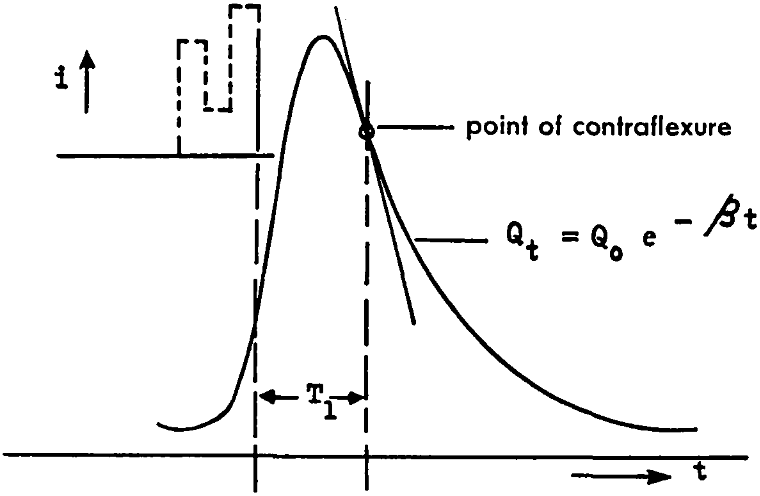
In the analysis of the observed hydrographs it is not necessary to know anything about the runoff producing rainfall except its time of ending.

It is not necessary to know the peak value or the absolute values of the discharges, only the rate of decrease indicated by the exponent β.

Thus with a minimum of data a hydrograph can be computed.

The writer checked this method for some river basins in Japan for which "complete" rainfall data and hydrographs were available and found a good agreement. Other good results were obtained by *Johnstone* (lit 2).

Mention should also be made of a promising looking method proposed by *Larrieu* (lit 4 and 5). Further checking is certainly worthwhile.



Soil moisture determination

One of the main obstacles in hydrologic studies of surface and groundwater when data are inadequate is the uncertainty about the amount of soil moisture. It is not so much the absolute amount that counts as the changes during a certain period of time. The usuai method of gravity sampling is not workable in river basins. Thus the determination of soil moisture storage is a major difficulty in studies of the water balance over comparatively short periods, in flood forecasting where the "losses" must be known, in determining recharge of groundwater, etc.

Fortunately, in the last few years a simple device has become available to accurately measure the soil moisture content without disturbing the soil. It is based on the scattering and moderation of fast neutrons by hydrogen atoms and the subsequent count of slow neutrons as a measure of the moisture content (neutron logging). Too little use in hydrologic studies is made of this simple and rapid device which was first introduced in the U. S. A. and U. S. S. R.

Good experiences have been acquired in Holland with the d/M-Gauge of Nuclear-Chicago Corporation. One of the advantages is the possibility to measure the changes in soil moisture content in one and the same point. In this way the effect of inhomogeneity of the soil is partly eliminated.

This device is both a tool for refined studies and for preliminary investigations. The most effective use is made if measurements are performed at regular intervals in a number of fixed key-stations in the river basin or in the experimental sample plot. A correlation can then be established between the readings at these stations and the true average moisture conditions of the area under consideration.

For determining free water evaporation and potential evapo-transpiration when no extensive measurements can be carried out, the best technique is still that based on the energy concept. The well-known formulae of *Penman* uses current meteorologic data. The reliability

Appendix I

Surface Water Hydrology

Investigations according to the Stage of the Project

Tentative project Feasibility survey	Preliminary project	Master project	Operation
Meteorological records Penman evaporation Turc's technique	Totalizers Evaporation pans	Recording rain gauges Measurement of solar radiation Snow survey	
Geomorphological map, geological map and soil map	Infiltrometer tests	Sample experimental area	Routine observations
Flood marks Information from local people Regional empirical formulae Transposition of data	Stage-discharge relationships Clark's method	Stage recorders Unit hydrograph Flood routing Assessment of empirical relations	Standard methods
	Analysis of depletion curves	Relation with groundwater conditions Observation wells	
		Soil moisture measurements	

can be substantially increased if measurements of net radiation are performed with the instruments which are now available.

Another technique which may be used where there are deficiencies in data is that proposed by *Turc* (lit 6).

The table of Appendix I gives a tentative outline of the methods in surface water hydrology according to the stage of the project and available funds for investigations.

2. Groundwater Hydrology

In groundwater investigations there is a need for methods yielding average values over large areas for the geotechnical constants and the flow rates.

The mathematical treatment of groundwater flow has been developed to a certain degree of perfection. Much attention has been paid to the analysis of pumping tests to obtain accurate data. These tests, however, yield information over comparatively small areas and adequate coverage of large areas meets the objections of time and funds. The main obstacle in groundwater investigations of large areas is not the mathematical treatment but the uncertainty about the geotechnical build-up and geotechnical constants.

The following points require further attention:

a) The assistance of a geologist familiar with groundwater problems in the first stage of the investigations and in the more detailed survey. There is still a gap between the approach by the engineer and the geologist.

b) The use of an ecological survey (vegetation associations) to detect zones of seepage, saline groundwater, variations in groundwater table elevations, etc.

c) The integration of agro-hydrological data and the soil survey in the concept of the conditions of the groundwater. Data on depth and variations in depth of the shallow groundwater table, permeabilities of the top layers, infiltration capacities, etc., are most useful. The engineer should be familiar with the way of thinking of scientists in allied fields. He should spend part of his time in the field in the company of a geologist, an ecologist and an agronomist. Engineers are too much inclined to rely on a study at the writing-desk of bore-logs, tests, maps and other data of their own discipline.

d) The study of the existing natural groundwater flow. In many cases much can be learned from an investigation of the areal pattern of piezometric heads, depths of the shallow groundwater and dry weather discharge of rivers. This will automatically yield figures as averages over large areas.

e) The study of the relation between the hydrologic conditions of the surface waters and the groundwater conditions (infiltration capacities, flood type, evaporation, dry weather discharges, etc.).

The following geotechnical constants in natural aquifers of considerable areal extent may be determined by the methods outlined.

Transmissibilities may be determined from:

a) The shape of the depletion curve (hydrograph withdrawal from groundwater storage). Simplified,

$$Q_t = Q_o \, e^{-\alpha t}$$

$$\alpha = \frac{10 \, kd}{pl^2}$$

where:

Q_t = outflow from groundwater at time t
Q_o = outflow from groundwater at time t = o
kd = transmissibility
p = effective porosity
l^2 = width of aquifer between water courses.

b) The draw-down of the groundwater table at various distances from an open water course where the water table falls suddenly.

The draw-downs in observation wells at various distances from the water course are read as a function of time. From the rate of draw-down the value of $\frac{kd}{p}$ can be computed.

c) The discharge of an effluent river and the hydraulic gradient of the isopiestic lines.

This requires accurate measurements of the base flow of a river in two points.

d) The known recharge of an aquifer and the hydraulic gradient of the isopiestic lines.

e) Permeability tests on disturbed samples comparing the results of tests on samples with a loose packing and a very dense packing. In this way the upper and lower limits of the permeabilities can be ascertained.

The resistances of semi-pervious layers may be determined from:

a) The seepage rate as determined by the water balance and the difference in elevation between the piezometric level and the level of the shallow groundwater table.

b) The variation of the piezometric heads in the direction of the groundwater flow in combination with the water balance.

c) The differences in piezometric heads at various depths in the same location in combination with other data.

Appendix II

Groundwater Hydrology

Investigations according to the Stage of the Project

Tentative project	Preliminary project	Master project	Operation
Feasibility survey			
1. *Geological reconnaissance* Field inspection by the geologist Collection of available data Consultation aerial photographs	1. *Test boreholes* Geophysical well logging	1. *Geological survey*	
2. *Geo-hydrological reconnaissance* Inventory of existing wells Water table fluatuations Elevation Water samples Seepage survey Information from local people	2. *Hydrologic survey* Discharge of rivers; base flow Intake capacities	2. *Geo-hydrological survey* Network observation wells Pumping tests Recharge of groundwater	Routine observations Standard methods
3. *Ecologic survey* Groundwater depth Rainfall Seepage zones	3. *Electric resistivity survey* (preliminary)	3. *Geophysical survey* Resistivity survey Geophysical well logging Seismic survey	
	4. *Agro-hydrologic data*	4. *Geo-hydrological maps*	

The recharge of groundwater may be determined from:

a) Depletion curves of river flow.

b) The discharge of springs.

c) Measurements of soil moisture conditions by neutron-logging.

The use of geophysical devices in groundwater investigations is also suitable for preliminary investigations when, with limited funds, a maximum amount of information is wanted.

The most powerful tool for groundwater investigations is found in the method based on measuring the electric resistivity of the formations in the subsoil. An important advantage is that the measurements can be carried out on the surface and the costs and time involved in a resistivity survey are only a few per cent of the costs of a drilling programme.

For the interpretation of the resistivity data the logs of some testholes at corresponding locations are necessary. The number of boreholes, however, can considerably be reduced if the drilling programme is combined with a resistivity survey.

In those areas where no data on the subsoil based on bore-logs are available, the results of the resistivity survey can conveniently be used to find the most characteristic locations for the testholes. As soon as these have been drilled, an interpretation for the whole area becomes possible.

Geophysical well logging (spontaneous potential, resistivity and neutron response) should be used wherever a great number of holes of considerable depths have to be sunk.

Matters of Policy in Connection with Hydrologic Investigations

The considerations on matters of policy in development will be limited to hydrologic investigations. In this field distinction has to be made between the short-term needs and the needs for a longer term.

The former refer either to areas where projects are initiated or contemplated in the near future or to works under execution to ensure an efficient operation. The need for collecting data in these cases is rather obvious and, provided that sufficient funds and personnel are available, the implementation of a programme of investigations is usually readily accepted.

Long-term needs apparently have a less urgent character. *Langbein* states: "The history of funds for basic-data programme shows that stations are usually established to meet some existing or pressing need.

for information. The result is an unbalanced network with an excess of information in some areas and gaps in others, which complicates the solution of new problems when they arise, because there are no suitable base stations and there is no time to collect the long records needed."

1. *Short-Term Needs*

For *major* projects the policy should be to implement the hydrologic investigations and the hydrologic design as an individual part of the project preceding the technical design.

This policy presents the following advantages:

a) More attention can be given to the hydrologic aspects of the project.
b) The feasibility of the project as far as depending on hydrologic factors can better be judged.
c) Gaps in the data and necessary further investigations can be defined clearly.

The separation of hydrologic investigations or design from the technical design applies either to the master plan or to both the preliminary and the master project.

The collection of the hydrologic data should be guided by the progress in the technical design according to the three stages mentioned earlier. In this way collection of unnecessary data will be avoided and the most important data can be collected first.

2. *Long-Term Needs*

A primary item in any long-term basic data programme is the establishment of a standard network of routine hydrologic investigations. Experience shows that the planning of such a network is a most difficult matter. In recent years the World Meteorological Organization (W. M. O.) has extended its activities to technical assistance in the field of surface hydrology by the establishment of a Commission of Hydrometeorology. A high priority has been assigned to networks and forecasting. The first publication on network design has been issued (lit 3). A guide on Hydrological Meteorology is now under preparation.

In connection with long-term needs, mention should be made of the use of representative sample areas. In these areas of comparatively small size, detailed hydrologic data are collected which can be transposed to larger areas for which they are representative and where data of general nature are collected. Reference can be made to publications by *Rodier* (lit 8). A similar objective is found in the UNESCO's long-term programme of research in scientific hydrology.

Considering that the ultimate goal of all assistance must be the self-activity and independence in technical matters, the following criteria are suggested for the implementation of hydrologic programmes:

a) The programmes should be an essential element of the development projects. These projects have a high priority within the social and economic policy of the country.

b) The programmes should include an element of dissemination of information and knowledge. Data collected by investigations in the area are most suitable material for instruction.

c) The programme should extend over a limited period of time, fixed beforehand. The duration may be of some 2 to 5 years.

d) Targets and expected results within this period of time should be exactly defined when embarking on the programme.

e) There should be a guarantee for a follow-up of the programme after its completion. Continuation should be considered as one of the regular activities of the government.

f) The country concerned should share in the costs of the programme and give material support.

g) The project-leader should be appointed as early as possible, i. e. in the stage of the negotiations with the country concerned.

References

1. Hydrologic Networks and Methods, Flood Control Series No 15, Bangkok, 1960, ECAFE — W.M.O.

2. *Johnstone* and *Cross:* Elements of Applied Hydrology, The Ronald Press Company, New York, 1949, pp. 226—234.

3. *Kohler,* Max A.: Design of hydrological networks; *Linsley,* Ray K.: Techniques for surveying surface — water resources, Technical Notes No 25 and 26, World Meteorological Organization, 1958.

4. *Réméniéras,* G.: Hydrologie de l'ingénieur, Eyrolles, Paris, 1960, pp. 362—369.

5. *Larrieu,* J.: Evaluation des crues catastrophiques par la méthode des hydrogrammes synthétiques, Proceedings International Assocation for Scientific Hydrology, Toronto 1957, vol. III, pp. 160—173.

6. Water deficiencies in European Agriculture, a climatological survey, International Institute for Land Reclamation and Improvement, Veenman, Wageningen, 1959.

7. *Brill*, E. J.: Geophysical surveys in mining, hydrological and engineering projects, European Association of Exploration Geophysicists, Leiden, 1958.

8. Inter-African Conference on Hydrology, Nairobi, January 1961; Commission for Technical Co-operation in Africa South of the Sahara (CCTA) and Scientific Council for Africa (CSA).

VIII. Mapping and Photo Interpretation

by E. Gigas

Beyond any doubt: Mapping is one of the most important prerequisits in all fields of any technical work in highly civilized countries and even more so in developing countries. It is quite clear, the old classical methods which were used in European countries cannot be used anymore in newly developing areas. If we consider the time, needed for the measurement and adjustment and computation of the basic control nets of first to third order (in Germany: 80 years! and the same time was needed to complete the topographical survey and mapping) and compare it with the time available for such tasks in the newly developing countries, it becomes quite obvious that only modern techniques can be used to fulfill the urgent demands in cartographic work.

Since the Second World War, we have learnt to apply new electronic methods and devices for geodetic and cartographic purposes. Canada has used the Radar method to complete the whole first order triangulation of an area of the size of Europe within six years. The methods called *"Shoran"* (short range detection) or the improved *"Hiran"* (high precision short range detection) are usually applied today in geodesy for very large areas. The principle is to measure the time which an electromagnetic pulse needs to run from the beginning of the unknown distance to the end and back to the starting point, by means of an electronic tube (tube of Braun). The rotating electronic beam writes a circle on which the pulse of the transmitted and the received echo are marked by pips. By changing the frequency of the transmitted wave it is possible to represent in the circle 100 miles, 10 miles, 1 mile, 1/10, 1/100, 1/1000 of a mile, and the distance can be determined figure by figure. In order to avoid the construction of high signals for overcoming the curvature of the earth, it is necessary to measure from a plane, starting with the measurements to both sides already before crossing the line. By an adjustment it is possible to determine the distances to the two trigonometrical points in the moment of line-crossing. Repeated measurements give a mean error of about 1 to 2 m. at distances of several 100 km. This means an accuracy comparable with classical first order results (1 : 200,000 to

1 : 300,000). The observer in the plane has to keep to pips on the two echos in coincidence with the pips of the transmitted pulse and a cine-camera photographs in very short time intervals the digital readings of the dials. With this equipment the basic control net of Persia was measured within one year.

The basic idea of this method is being used in two other instruments: the Geodimeter and the Tellurometer. The Geodimeter is built in three different models. The smallest one is being used to measure distances up to 5 or 8 km, the largest one for distances up to 30 to 40 km. The Geodimeter uses high frequent modulated light waves (8 to 10 MHz). The accuracy is very high, distances of several kilometers are measured with an accuracy up to a few centimeters. Only half an hour is needed for one measurement with the Geodimeter 4 B.

High frequent modulated electro-magnetic waves are used by the Tellurometer. It allows measurements even in hazy or foggy weather. Distances of 3 to 25 km, even up to 60 km can be measured within half an hour.

It is evident that in modern surveying the determination of control-points is preferably done by measuring the length of sides instead of measuring the angles. This means that the triangulation is nowadays very often replaced by trilateration. By using trilateration the time required for the measurement of the basic control including determination of control-points for photogrammetry is reduced considerably, and this method is the best one to be applied in developing countries.

In the field of leveling there are some improvements, too, but they are not comparable with those mentioned before. Semi-automatic leveling self-adjusting levels reduce the time required for vertical control measurements to a fifth of the time required for the former classical methods. However, in the near future we may expect the development of entirely automatic leveling methods. Russia and the U. S. A. have developed instruments using pendulums and photographic registration, installed in motor cars which allow to determine height differences with an accuracy of about one foot. The daily output is about 150 to 200 km, i. e. 50 times more than with normal leveling methods.

Today topographic survey is almost without exception performed by air-photography. Aero-triangulation is applied if the control net is wide meshed. Several flights in high altitudes enable the control net to be condensed and to furnish the base for the topographic compilation in larger scales. The Stereoplanigraph is one of the best instruments to guarantee high accuracy in aero-triangulation. The instruments of second and third order secure a high efficiency in topographic mapping. By using the Stereoplanigraph or a similar high precision stereo-plotter it is possible to scribe in separate colors the black situation, the brown contours and the blue water-features on different transparent foils. But the normal compilation by means of a plotting instrument, today, still takes much time. Even well trained personnel will need two to three weeks to draw a sheet of 1 : 5,000 scale, and six to eight weeks to draw a sheet of 1 : 25,000 scale.

The usual rectifying instruments provide only in flat areas pictures of topographic objects without horizontal displacement. In mountainous areas, however, it is not possible to avoid very large displacements. Air photogrammetry is a central perspective and not an orthogonal projection as it is represented by a map.

New constructions, the Orthophotoscope by Bean (U. S. A., Geological Survey) or the Orthoprojector by Zeiss-Aerotopograph, furnish completely correct orthogonal pictures which are obtained very quickly from air-photographs by a semi-automatic process. These airphotos which are entirely free of any displacement of topographical objects can replace a map. Such maps will meet even the requirements of a Cadastral Survey Service, because they show every detail visible in nature. This is very important, especially for geological reconnaissance.

In the near future we may expect to obtain such information completely automatically by a newly developed instrument, the Stereomat. This instrument compares the corresponding micropictures of the same object in the two photographs of a stereomodel. By scanning the neighbourhood of the observed object, the integrated effect of the changing density, i. e. the changing intensity of a light beam, is compared by photocells and is being used to restrain the position of the floating mark. The scanning required to obtain an orthophotoscopic picture, is already executed fully-automatically in the Orthoprojector and Orthophotoscop. The Stereomat will replace the operator who during the scanning has to keep the floating mark in contact with the terrain. This means an important new step forward and will facilitate considerably the quick production of good photographic maps.

After these few remarks regarding the modern revolution in geodetic and cartographic methods, I will try to explain the actual value of photogrammetric pictures for the many purposes of geological investigations for geographical and hydrographical purposes.

Photo interpretation is a very valuable help in all geological research work and investigations, but it requires well trained personnel with wide experience. The expert should know the fundamentals of morphology, geology and other earth sciences. Well trained personnel are able to make use of the information contained in air-photos for soil survey, agricultural and engineering material analysis, drainage studies, land use survey, hydrographic research, mineral exploration and groundwater location. Connected with interpretation work, preceding studies are being made of all available literature on geology, climatology, hydrology, stratigraphy and a collection of all technical data which may furnish information on the physical conditions of the area.

If we start with an investigation of groundwater location, an extensive study of the terrain characteristics in the air-photo is necessary. Robert *Howe*[1] says: "The pattern of each 'wrinkle' of the earth, the shapes of gullies, the patterns of streams and their tributaries, the tonality of shading of the photograph of an area, and other recognizable features photographed all provide valuable information for the interpreter-engineer analyst." Also the vegetation as observed in the photos can provide important knowledge of the surface materials or the topographic condition. "Tonality or shading tones of the vegetation on air-photos may provide considerable information about the texture or moisture content of the soil." If the land is used, the interpreter will have some hints in determining soil types. Often the topography is also an indication of soil types and geological formations. "Drainage features exhibit very definite characteristics in certain types of soils and subsurface formations, i. e. the appearance of the cross section of a gully, the gradient of the gully and the pattern of the drainage features."

"Special ground features, such as kames and eskers, terraces, alluvial plains, lake beds, grave pits and quarries are recognizable and represent certain types of surface and subsurface materials."

Groundwater has to be expected, if porous or granular water-bearing formations are visible on the air-photo and its comparisons with pictures of similar, already investigated topographic and geological nature. Favorable ground conditions such as location and elevation, important to the ground water storage and movement may be identified on the photograph.

After the interpretation of the photos (f. i. scale 1 : 30,000) a short field inspection usually follows. The individual areal photos are put together to form a mosaic in the scale 1 : 50,000. In this picture the different layers can be drawn. The above mentioned reconnaissance in the field allows the kind of surface materials to be determined and the

---

[1] Robert H. L. *Howe*, Procedure of Applying Air Photo Interpretation in the Location of Water. — Photogr. Eng. 1958.

corresponding areas to be marked in colour. The preceding interpretation in the office helps to accelerate the measurements in the fields and prevents certain determinative features being overlooked. The time required for producing such a geological map is only one fifth of that time which would have been required without a photo-interpretation. Very often it will be sufficient to investigate only a part of the terrain in the field and to extend the inferences taken from this part to the whole area.

Very often infrared pictures show more details than photographs on normal films. Infrared pictures need a longer exposure (4 times) but give drainage details much clearer than normal photography.

The accuracy of a stereo-plotting depends on the scale of the pictures and the angular aperture of the camera. The scale depends on the focal length and the flight height. These facts lead to the selection of the camera type.

Points of good visibility in the picture have an average mean error in coordinates of 10 μ in the scale of the picture. The accuracy of the heights is normally 0,1 ‰ of the flight height.

The pictures taken with infrared optics on infrared film show many more details than normal photographs. Water areas and coast lines, small rivers, creeks are better to identify. It is preferable to use Pan-film to show objects lying under the surface of the water, like sands and reefs, etc.

In case the different materials on the ground have different temperatures (i. e. water and land areas, rocks and soil, etc.) the distinction of the different geological features is easy to recognize.

A modern survey starts with the general reconnaissance and with the marking on the ground. Then follows the determination of vertical and horizontal control by using modern electronic instruments. Subsequently the aerial photography is performed, followed by the plotting of planimetry, drafting contours, measuring cross sections, and the determination of the bench marks.

In the field a direct survey of profiles of water surface and ground is made and photo mosaics are prepared for geological reconnaissance. Reproducing or printing of the maps is the last step.

As a geodesist I am not quite familiar with geological science and interpretation. But I am always astonished to see what an expert is able to recognize from an air-photograph.

Colored aerial photography can very often stress the geological information. But there are cases where black-white photography is preferred, for instance to recognize the alluvial and slope-wash deposits. But colored photographs may considerably shorten the time for geological interpretation. However, many problems are still unsolved.

In conclusion I will not forget to mention some other airborne instruments, which may contribute valuable information: the airborne magnetometer and the airborne scientillometer. They are especially applied in the search for sulphides of copper, lead and zinc.

The planes, normally two parallel flying aircrafts, 300 m spaced, in about 150 m height, tow a streamlined "bird", which is about 110 m above the ground. It carries a generator, producing an alternating electro-magnetic field. A secondary field is produced in the ground, and the resultant is recorded in the instrument. In the aircraft are carried: a total force magnetometer, a vertical component magnetometer and a radio activity detector, a 35 mm vertical tracking camera, and a radio altimeter.

Subsequent analysis of a sortie therefore entails the correlation of the records of the different instruments. The film of the tracking camera gives the relation to the photo mosaic.

Very large areas can be explored by means of this method. Modern surveying and new methods of interpretation are important tools in the hands of hydrological engineers and I hope that in this century the geodesist will become the cooperator of the geologists and hydrologists, and that he will be able to deliver the material at the right time which is needed for all technical problems of development.

References

1. *Fischer*, William A.: Color Aerial Photography in Photogeological Interpretation. Photogr. Engineering. Sept. 1958, p. 545 ff.
2. *Tator*, B. A.: The Aerial Photography and Applied Geomorphology. Photogr. Engineering. Sept. 1958, p. 549 ff.
3. *Lattmann*, Lawrence: Technique of Mapping Geological Fracture Traces and Lineaments on Aerial Photographs. Photogr. Engineering. Sept. 1959, p. 568 ff.
4. *Kedar*, Yehuda: The Use of Aerial Photographs in Research in Physiogeographic Conditions and Anthropogeographic Data in various Historic Periods. Photogr. Engineering. Sept. 1958, p. 584 ff.
5. EIRA-Chronicle. Italmap pamphlet 5/6.
6. *Becking*, Rudolf W.: Forestry Applications of Aerial Color Photography. Photogr. Engineering. Sept. 1958, p. 559—564.
7. *Theurer*, Charles: Color and Infrared Experimental Photography for Coastal Mapping. Photogr. Engineering. Sept. 1959, p. 565—569.

8. *Dill*, Henry W. Jr.: Use of the Comparison Method in Agricultural Airphoto Interpretation. Photogr. Engineering. March 1959, No. 1, p. 44—49.

9. *Lueder*, Donald: The Principles and Applications of Aerial Photographic Interpretation.

10. U.N. Third Regional Cartographic Conference for Asia and Far East. 27 Oct to 10 Nov 1961 at Bangkok. Item 16 and 17 of the official report, published 1962 by the U.N.

IX. Die Mitarbeit der Geologie, Geophysik und Bodenkunde bei dem Ausbau der natürlichen Wasservorkommen in Entwicklungsländern

(The Contribution of Geology to the Development Work of the Natural Water Resources)

von H. Flathe, H. Kleinsorge, O. Strebel und E. Schönhals

Einleitung

Die Geologie beschäftigt sich in ihren Fachrichtungen Ingenieurgeologie, Hydrogeologie, Geophysik und Bodenkunde auch mit den natürlichen Gegebenheiten von Wasservorkommen. Sie wird deshalb bei der Aufstellung von Ausbauprojekten solcher Vorkommen zur Mitarbeit herangezogen, seien es Eingriffe in den Oberflächenablauf, in den Abstrom des Grundwassers oder auch Fragen der Verwendung des Wassers in Bewässerungsprojekten. Der Geologe nimmt in dem größeren Team der Bearbeiter von Wasserentwicklungsprojekten einen mitbestimmenden Platz ein. In vielen Ländern ist seine Mitarbeit schon gesetzlich verankert.

Der Inhalt und die Methodik der geologischen Mitarbeit in derartigen Projekten ist allgemein gesehen in allen Teilen der Welt gleich; sie werden durch die Einzelzüge der Geologie des Projektgebietes und den Umfang des Projektes bestimmt, sie variieren deshalb im Einzelprojekt stark. Es mag aber von Interesse sein, die allgemeinen Grundlinien und die neueren Erfahrungen vom geologischen Gesichtswinkel her kurz zusammenfassend zu überblicken, um für Arbeiten in Entwicklungsländern eine Vorstellungsbasis der Aufgaben, der Begrenzungen und der Möglichkeiten der geologischen Arbeitsmethode herauszustellen.

Geologische Mitarbeit bei dem Ausbau der natürlichen Wasservorkommen

1. *Groß-Wasserbau*

Alle großen Wasserbauprojekte — von denen die Projekte von Stauanlagen stellvertretend für viele Arten von Vorhaben betrachtet werden können — bedeuten einen entscheidenden Eingriff des Menschen in die natürlichen Gegebenheiten und den Ablauf der von vielen inneren und äußeren Faktoren beeinflußten natürlichen Entwicklung in dem speziellen Ausschnitt der Erdkruste. Die Beiträge der Geologie zu solchen Projekten werden hauptsächlich die nachfolgenden drei Fragenkomplexe erörtern müssen:

a) Die regional-geologische Eingliederung des Projektgebietes in den großen geologisch-strukturellen Rahmen und die geomorphologische Entwicklung der in Frage stehenden Landmasse.

b) Die geologischen, hydrogeologischen und gesteinsmechanischen Fragen des Einflusses des Projektes auf die natürlichen Gegebenheiten des vorhandenen, beanspruchten Gesteinsverbandes.

c) Die geologischen, hydrogeologischen und gesteinsmechanischen Fragen der im Einzelfall notwendigen Vergütungsmaßnahmen im tieferen Untergrund der Stauanlage mit einer durch Labor- und Feldversuche gesicherten Beurteilung der diese Maßnahmen beeinflussenden geologischen Faktoren des Gesteinsaufbaues.

Alle drei angeführten größeren Fragenbereiche finden ihre Beantwortung durch eine umfassende geologische Bearbeitung und die Aufschlußerkundung des Problemgebietes, die in Verbindung mit Vorstudien und Übersichtsbegehungen zur Einordnung in den größeren regionalgeologischen Rahmen durchgeführt werden. Es kann nicht der Zweck dieser Übersicht sein, auf die einzelnen, sich aufeinander aufbauenden Schritte des Untersuchungsablaufs näher einzugehen und die einzelnen Probleme abzuwägen; es soll nur festgestellt werden, daß die Untersuchungen schon für die Vorplanung von größerer Bedeutung sind, daß ihr Umfang nicht nur von der Größe des Projektes, sondern weitgehend auch von den lokalen und regionalen geologischen Verhältnissen abhängt und daß sie — sofern technische Aufschlußerkundungen nötig sind — häufig lange dauern.

Die zu lösenden Aufgaben gehen sehr oft über die Möglichkeiten selbst eines in diesen Arbeiten erfahrenen Einzelarbeiters hinaus und können heute nur noch von Fachinstitutionen oder Fachteams übernommen werden. Neben den untersuchenden *Feldgeologen* für die Bearbeitung der strukturellen, stratigraphischen und petrographischen Fragen der Gesteinsverbände und der geomorphologischen Fragen des Gebietes, tritt der *Geo-*

ingenieur für die Durchführung und Auswertung der Aufschlußerkundung, der *Bodenmechaniker* für die umfassende Untersuchung und Bewertung von Lockergesteinen, der *Felsmechaniker* für die Bestimmung der Isotropieverhältnisse des Festgesteinskörpers, der *Hydrogeologe* für die Bearbeitung des Grundwasserabstroms und der Durchströmungsverhältnisse des Gesteinsverbandes, der *Geophysiker* für die Vertiefung der Erforschung der lokalen und regionalen strukturellen Verhältnisse und endlich der *Bodenkundler* für Untersuchungen im Bereich seichter Staubeckenränder und die Bewertung der Böden in vorgesehenen Bewässerungsgebieten. Je nach den Verhältnissen des Problemgebietes wird der Einsatz der einzelnen Bearbeiter einen mehr oder weniger großen Umfang haben.

2. *Grundwasseraufschluß*

Die Projekte des Grundwasseraufschlusses und der Grundwassernutzung — mag es sich dabei um Projekte zur Wasserversorgung der Bevölkerung oder um Projekte für die landwirtschaftliche Bewässerung handeln — stehen in engster Abhängigkeit von dem geologischen Bau und der langzeitlichen Entwicklung der Problemgebiete. Die Beiträge der Geologie in diesem Zweig des Ausbaues der natürlichen Wasservorkommen sind daher von primärer Bedeutung; sie werden hauptsächlich die nachfolgenden drei Fragenkomplexe klären müssen:

a) Den strukturellen und den Schichtaufbau des Problemgebietes zur Bestimmung des Auftretens und der Verbreitung möglicher Grundwasserleiter jungen oder höheren Alters.

b) Die Fragen nach den Infiltrationsgebieten der gefundenen Horizonte, nach den möglichen Infiltrationsanteilen an den heutigen Niederschlägen und nach der Möglichkeit des Auftretens „fossiler" Grundwässer früherer, regenreicher Zeitperioden.

c) Die Fragen der Transmissibilität, des Chemismus und der Erneuerung der Grundwasservorkommen, die eine Berechnung der nutzbaren Grundwasservorräte und die Aufstellung eines Nutzungsplanes ermöglichen.

Die zur Beantwortung der angeführten Hauptfragenkomplexe notwendigen Untersuchungen sollen die Beschaffenheit des Grundwasserleiters und seine Lage im Raum so weit klären, daß eine auf feste Daten gestützte Übersicht über seinen Wasserhaushalt gegeben werden kann. Die Daten sollten der Nutzungsplanung zugrunde gelegt werden, und es sollte durch Verwaltungsmaßnahmen sichergestellt werden, daß dieser gegebene Rahmen nicht durchbrochen wird. Überschreitungen der Entnahme führen zu den bekannten, vielerorts auftretenden Grundwasserkatastrophen, die teilweise irreversibel werden können.

Die angeführten Aufgabenkreise gehen über die Möglichkeiten selbst eines in diesen Arbeiten erfahrenen Einzelbearbeiters hinaus. Sie werden heute von größeren Fachteams in Angriff genommen. Neben den *Feldgeologen hydrogeologischer Fachrichtung* zur Untersuchung der geologisch-stratigraphischen, der petrographischen und palaeogeographischen Fragen und den *Geohydrologen* zur Bearbeitung des Wasserinhaltes des Grundwasserkörpers tritt mitbestimmend der *Geophysiker*, der durch geoelektrische und angepaßte seismische Untersuchungen einen großen Teil der Bohraufschlüsse ersetzen kann und relativ schnell die Aufstellung von großregionalen Bildern ermöglicht (s. u.). Ein weites Arbeitsgebiet findet auch der hydrogeologisch ausgerichtete *Geoingenieur*. Die maßgebliche Rolle des *Bodenkundlers* bei Bewässerungsvorhaben wird weiter unten näher betrachtet.

Zur Methodik der geologischen Mitarbeit bei dem Ausbau der natürlichen Wasservorkommen in Entwicklungsländern

Die in dem Kapitel 2 kurz zusammengefaßten Problemstellungen und Arbeitserfahrungen auf dem Gebiet der Mitarbeit der Geologie in Wasserbauvorhaben sind heute schon weitgehend Allgemeingut. Sie sollten aber in den Entwicklungsländern besonders sorgfältig ausgewertet werden. Hier — in den im allgemeinen schwächer besiedelten Landstrichen und bei den meist durch Voreingriffe unbelasteteren Verhältnissen — können die durch eine systematische Grundlagenforschung auf dem Gebiete der Geologie festgestellten Möglichkeiten in einem Generalplan besonders wirkungsvoll ausgeschöpft werden. Die Hilfe der Industrieländer für die Entwicklungsländer auf diesem Gebiet wird daher häufig von erstrangiger Bedeutung für den Aufbau sein; sie wird um so wertvoller, je frühzeitiger und umfassender sie geleistet werden kann. Es empfiehlt sich, derartige Hilfen mit der Schulung einheimischer Sachbearbeiter zu verbinden. In allen Arbeitsbereichen können die geologische und auch die bodenkundliche Feldaufnahme — früher oft die längstdauernden Teile der Gesamtarbeiten — heute durch den Einsatz aero-geologischer Methoden beschleunigt und verfeinert werden. Die moderne Luftbildauswertung nimmt dem Bearbeiter einen großen Teil der Felduntersuchungen ab. Die eigentliche Feldarbeit kann meist auf auswertende Kontrollbegehungen, die Feststellung von hydrogeologischen Zusammenhängen, von Altersverhältnissen, von petrographischen Einzelheiten und von Einzelzügen der strukturellen Gliederung des Gesteinsverbandes (in Zusammenarbeit mit Fels- und Bodenmechaniker) u. ä. beschränkt werden.

1. Geophysikalische Mitarbeit bei Wasserbauprojekten

Ein sehr ausgedehntes Arbeitsgebiet findet die Geophysik bei der Planung des Grundwasseraufschlusses. In der Bundesanstalt für Bodenforschung erwies sich der Einsatz einer Arbeitsgruppe aus Hydrogeologen und Geophysikern mit Geoingenieuren als außerordentlich erfolgreich bei Arbeiten im Inland und in den Entwicklungsländern, wie z. B. Pakistan, Syrien, Indonesien, Paraguay usw. Mit dem Feldgeologen bzw. dem Hydrogeologen wird stets der mit fahrbaren, speziell in der Bundesanstalt entwickelten geoelektrischen und seismischen Geräten ausgerüstete Geophysiker eingesetzt, der die auswertenden Lokalbefunde des Geologen relativ schnell regional ausbauen kann. Durch die geoelektrischen Arbeiten läßt sich der Verlauf der Begrenzungsflächen des Grundwasserleiters (z. B. Sand-Kies-Horizont, eingebettet in Tone oder Mergel) schnell für größere Gebiete festlegen. Diese Messungen liefern gleichzeitig auch zuverlässige Daten über den Materialaufbau des Horizontes, über die auftretenden Beimengungen von Tonen oder Mergeln, d. h. über das „Vertauben" des Grundwasserleiters. Eine besonders dankbare geoelektrische Aufgabe ist auch die Abgrenzung von Gebieten mit hochgradiger Grundwasserversalzung und die langfristige Überwachung der Grenze Salzwasser —Süßwasser. Um das Meßmaterial quantitativ auswerten zu können, wurden in größerem Umfange Auswertungs-Standardkurven erstellt. Zur Abgrenzung von aus Lockermaterial aufgebauten Grundwasserleitern gegenüber Festgestein eignen sich besonders die Methoden der flachen Refraktionsseismik. Hier sind neue Verfahren der Hammerschlag- und Fallgewichtsseismik in der Entwicklung und werden in naher Zukunft größere Bedeutung bei diesen Untersuchungen gewinnen. Die Frage nach dem Auftreten „fossiler" Wässer kann heute ebenfalls durch geophysikalische Methoden (C^{14}-Methode) beantwortet werden, so daß dieser häufig in Entwicklungsländern wichtige Faktor der Nutzungsmöglichkeiten der Grundwasserleiter weitgehend vorgeklärt werden kann.

Der Wert geophysikalischer Untersuchungsmethoden bei den Vorarbeiten zum Talsperrenbau braucht hier nicht im einzelnen aufgezeigt zu werden; größere Teile der Aufschlüsse werden heute durch geophysikalische Arbeiten ersetzt. Es mag von Interesse, besonders für die Entwicklungsländer, sein, daß sich auch geophysikalische Wege zur Erforschung der felsmechanischen Kennwerte der Festgesteinskörper in Talsperrengründungszonen andeuten, die vielleicht schon in naher Zukunft wertvolle Daten über das zu erwartende Gesteinsverhalten zur Verfügung stellen können.

2. *Bodenkundliche Mitarbeit bei Bewässerungsprojekten*

In beiden Arbeitskreisen, sowohl dem Großwasserbau als auch der Grundwassererschließung in Entwicklungsländern ist — sobald die Fragestellung des Projektes landwirtschaftliche Bewässerung einschließt — die volle Mitarbeit des Bodenkundlers in der geologischen Gruppe unerläßlich. Die bodenkundliche Untersuchung erstreckt sich auf die Bestimmung der jetzigen Bodeneigenschaften und ihre Veränderung durch die Bewässerung. Wichtig ist vor allem die Kenntnis der Wasserkapazität, der Durchlässigkeit und der Erodierbarkeit der Böden. Diese Faktoren sind von der Textur, der Struktur, dem Chemismus, dem Humusgehalt und der Mächtigkeit des Bodens abhängig. Es sind daher neben Bodenuntersuchungen im Gelände die verschiedensten chemisch-physikalischen Untersuchungen im Labor erforderlich. Die Ergebnisse (der Feld- und Laboruntersuchungen) kommen auf der Landklassifikationskarte zur Darstellung, die für jedes Bewässerungsgebiet zur Verfügung stehen sollte. Bei allen Bewässerungsprojekten in ariden und semiariden Gebieten ist der Bodenversalzung besondere Beachtung zu schenken. Aus diesem Grund müssen Angaben über die Grundwasserstände und deren Schwankungen im Laufe des Jahres sowie über deren mögliche Änderung unter dem Einfluß der Bewässerung vorliegen. Diese Angaben sind auch unerläßlich für Maßnahmen zur Entsalzung von Böden durch Auswaschung mit geeignetem Wasser. Die chemische Zusammensetzung des Wassers muß daher ebenfalls festgestellt werden. Eine weitere Voraussetzung für eine erfolgreiche Salzauswaschung ist ein mehrere Meter tiefer Grundwasserstand, was in vielen Fällen nur durch ein genügend tiefes und enges Entwässerungs- und Drainagesystem erreicht wird. Eine möglichst frühzeitige und ständige Zusammenarbeit zwischen Bodenkundlern, Hydrogeologen und landwirtschaftlichen Sachverständigen ist infolgedessen erforderlich.

Auch nach Vorliegen all dieser Forschungsergebnisse ist es besonders in Entwicklungsländern schwierig, Angaben über die Auswirkungen der Bewässerung auf die verschiedenen Böden und über den Anbau von landwirtschaftlichen Kulturpflanzen zu machen. Aus diesem Grunde ist es notwendig, landwirtschaftliche Forschungsstationen zu errichten, um in mehrjährigen Versuchen sichere Ergebnisse zu erzielen. Solche Stationen könnten gleichzeitig als Ausbildungsstätten für einheimische Landwirte dienen, soweit sie noch nicht mit der neuen Wirtschaftsweise vertraut sind.

Summary

The natural water resources represent an important factor in every national economy. We distinguish two types of natural water resources, viz. the surface run-off in rivers and streams and the groundwater. Both are dependent on a multitude of factors and therefore the planning of their use necessitates a team of investigators of different

technical and scientific disciplines. Amongst others, the work of the geologist in various branches of specialization will have an ample influence.

The Contribution of Geology to Projects and Construction Schemes in the Development of Surface Run-off can best be visualized by the geological work in dam construction because in this type of planning most other kinds of theoretical and practical river handling are represented. The task of the geologist in such projects will be to compile and consider basic data of three main spheres of problems:

1. The problems imposed by the adaptation of the project layout to existing geological conditions and the geological consultation of remedial foundation treatment methods and their application in the project area.
2. The problem of localizing the project as favourably as possible in the general frame of the geological units and structural belts of the landmass.
3. The problems of the evaluation of the various influences of the intended structure to existing natural evolution processes and the predetermination of the effects of new evolutional trends produced by factors that were newly introduced in the area by the construction.

To solve the multitude of involved questions the main task of the geologist consists in the study and meticulous statement of the natural surrounding of the project, of the existing rock units and their arrangements, of the structural, transformational and weathering processes influencing the material and their effects, of the discharge conditions of surface- and underground waters and of the recent and subrecent history and natural evolution of the area. All the results thus obtained and the stated facts will play an important role in the feasibility of the project; they may greatly favour or heavily weigh upon safety, construction procedures and costs of the development.

In order to guarantee a close and effective co-operation of the planning team, the geologist should from the very beginning participate in the discussions of such schemes, thus enabling him to incorporate the general geological features of regional and structural importance. Many unnecessary misunderstandings may result from an insufficient coordination of efforts.

The contribution of geology to the development of the groundwater resources of a country is known to be of primary importance. Also in this development work the geologist will have to coöperate with a team of investigators of different other branches of science. The regeneration of groundwater, its occurrence and composition and its optimal utilization are governed by a great many detailed items, and a very careful, many-sided research is needed before exploitation can start.

It is the first task of the geologist to locate and to define the spread, the composition, and the structural main lines of the geological horizon, which by its water content becomes an aquifer. In the course of the exploration, the hydrogeologist will have to clarify the minute details of the water-bearing material, its physical properties in vertical and horizontal directions, its specific yields and the composition and changes in composition of its water content by a series of tests and technical processes until a well defined picture of the aquifer is obtained. With the last step of the geological work, the detailed delineation of the occurrence and its detailed description on the maps, the main task of the geologist — here only very shortly summarized — will be finished and its optimal utilization can be planned.

Even nowadays the real value of a groundwater occurrence, the limitations of its recharge and specific yield by natural conditions is not always taken into due consideration. Wild cat drilling and overpumping are very common. For example in many parts of the great North-African aquifers which contain a high percentage of "fossil" water with no or only very insignificant recharge, the precious water is often wasted on unsuitable soils, leading to the formation of salt crusts instead of an improvement of the agricultural production. It seems essential, to stress the urgent necessity of a governmentally supervised regulation and distribution of groundwater, in particular in arid and semi-arid countries. Plans for the rate of extraction and priorities of use based upon detailed research should be enforced by strict laws in order to protect this most vital natural wealth against waste.

References

1. *Bender,* F., and *Flathe,* H.: Groundwater Conditions in the Chaco Boreal of Paraguay. Publication No. 57 of the IASH Groundwater in Arid Zones pp. 173—185, 1961.
2. *Berkey,* C. P.: Responsibilities of the Geologist in Engineering Projects. Am. Inst. Min. Metall. Eng. Techn. Publ. No. 215.
3. *Blee,* C. E.: Geology and Foundation Treatment. United States, Tennessee Valley Authority, Technical Report No. 22, Washington 1949.
4. *Burwell,* E. B., and *Roberts,* GD: The Geologist in the Engineering Organization. In *Paige,* S.: "Application of Geology to Engineering Practice", Geol. Soc. of America, Berkey Vol., 1950.
5. *Burwell,* E. B., and *Moneymaker,* B. C.: Geology in Damconstruction, ibid. p. 10—43.

6. *Louderback*, G. D.: Faults and Engineering Geology, ibid. p. 125—150.
7. *Flathe*, H., and *Pfeiffer*, D.: Outlines on the Hydrogeology of the Isle of Madura (Indonesia) — in print in Publications of the IASH.
8. *Meinzer*, O. E.: Geology and Engineering in the Production and Control of Groundwater, ibid. p. 152—179.
9. *Gignoux*, M., et *Barbier*, R.: Géologie et Barrages et des Aménagements hydrauliques. Masson et Cie., Paris 1955.
10. *Hvorslew*, M. J.: Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes. Rep. on a Research Project of the Am. Soc. of Civ. Eng., Vicksburg, Mississippi 1949.
11. *Israelsen*, O. W.: Irrigation Principles and Practices. — New York and London 1958.
12. *Keil*, K. F. G.: Geotechnik. Halle 1959.
13. *Keil*, K.: Der Dammbau. Berlin 1954.
14. *Kleinsorge*, H.: Die Standortplanung der Talsperren auf der anatolischen Halbinsel und ihre geologischen Grundlagen. Die Wasserwirtschaft, Jg. 51, H. 9, Sept. 1961, S. 233—241.
15. *Legget*, R. F.: Geology and Engineering. McGraw-Hill book Comp., New York and London 1939.
16. *Lugeon*, M.: Barrages et Géologie. F. Rouge Co., Lausanne 1933.
17. — Geotechnical Studies of Foundation Materials. 2nd Congr. and Large Dams, Washington 1936.
18. *Luthin*, J. N (Editor): Drainage of Agricultural Lands. Americ. Soc. Agron., Madison, Wisconsin 1957.
19. *Thorne*, D. W., and *Peterson*, H. B.: Irrigated Soils. New York and Toronto 1954.
20. U. S. Salinity Laboratory Staff: Saline and Alkali Soils. Agriculture Handbook No. 60, February 1954. U. S. Dept. of Agriculture.
21. Arid Zone Research — XIV, Salinity Problems in the Arid Zones. Proc. Teheran Symp. UNESCO, Paris 1961.

X. Hydro-Electric and Integrated River Basin Development in Less Developed Countries

by A. H. Naylor

Background

The opening up of underdeveloped countries has been by private enterprise operating through ports on the coast and trading posts along the rivers. In interior states development had in general to await access facilities such as railways. Trading posts were followed by large companies with plantations. Government involvement followed, increasingly securing its revenue from the trade and exports and providing roads and railways. Little power was required as materials were exported raw to be manufactured in Europe and this was easily provided by privately owned oil or steam engine plants. Hydro-electric power is only now being developed on a large scale. It was first used for the lighting of towns using small streams. Water power can, however, in general be developed most economically in a large quantity and this requires an industry such as aluminium production or electric processes with a large consumption of electricity, or alternatively distribution on a national scale. Until the last war government planning in these countries had been largely confined to transport and communication. Large hydro-electric development however interferes with and interacts financially and physically with alternative developments. It is therefore necessary that a plan of development should be worked out for the whole country or at least the whole of a catchment area.

Survey of Resources

First there must be a survey of existing and potential resources.

Of primary importance is availability of capital. The initial costs and delays may be reduced by making full use of cheap native labour. All power resources should be considered; coal, oil, peat, natural gas, geothermal, solar heat, atomic, water and wind power. Tidal power, use of solar radiation, and wind power have not as yet proved economical. Water power on the other hand is often very attractive though available hydrological data will probably be scarce and in need of supplementation.

Mineral deposits are of great importance, their high value giving a satisfactory early return on capital.

Then there are natural resources of forests, arable land and fisheries. Finally, the beauty of landscape, lakes, reservoirs, etc., form a potential tourist attraction.

Political

Under the Pax Britannica, steady, orderly development took place in the colonies and protectorates, the extent and rate being limited by the need to spread a limited amount of available capital or by deliberate policy, in the native's interest in the protectorates, the native small holder being safeguarded by the exclusion from the country of large businesses.

With independence the countries themselves are impatient of development. As there is now little security for capital investments finance is sought from any source, such as the World Bank. Full advantage is taken of the competition between America and Russia in providing capital, each with a view to excluding the other.

Optimum Development

1. *Definition*

Optimum Development must now be taken to mean "in the best interests of the country". This requires definition; it can be measured in terms of material prosperity or full employment; by no means the same thing. Should ultimate optimum development or the present value of future returns be the criterion?

2. *Period of Planning*

Civil Engineering works are almost everlasting but it is normal to plan for a life of the order of 80 years, with much shorter periods for machinery — 40 years for hydro-electric and mechanical machinery and 30 years for electrical apparatus. In view, however, of the rapid development of new forms of power and sources of fuel, a shorter period should be used in making an assessment.

3. *Increase in Demand*

An estimate of demand is extremely difficult in under-developed countries. In Europe, where conditions are much more stable, there is a doubling of consumption every decade. In under-developed countries, in addition to the normal increase, there are factors such as increasing population with increased prosperity and increased consumption per head.

4. *Water*

A vital factor in the economy is the availability of water and the need to distribute this to every part. This has its repercussions in hydro-electric planning.

5. *Land Use*

In any optimum development common prudence dictates a diversity in land use. There is also a need to strike a balance between conflicting uses. Initially this aspect may not arise but it is important in the ultimate planning and of immediate importance with large schemes as, for example, the Volta Scheme involving the flooding of over 3,000 square miles. It is not sufficient to assess this land at its present value but rather at its potential value if unsubmerged. Policy with regard to preservation of land for stock rearing and semi-nomadic tribes needs to be settled when estimating the amount of land available, and which can be made available with irrigation, for crops to support the expected population.

Role of Hydro-Electric Power

Whilst small amounts of power only can be absorbed initially, it is often only in large schemes that hydro-electric power can be provided at low cost. In such cases economic development requires industry consuming a large quantity of electricity such as the production of ores and electro-chemical processes. However, small schemes may often be found to be economic and capable of immediate development.

As water power is a non-wasting asset, full development as soon as possible will bring the greatest wealth to the country. It may often be economic to import the raw materials required for processing as for example, the import of bauxite for the Volta scheme.

Hydro-electric power schemes are normally located well in the interior of a country in the higher regions, together with thermal stations normally located at the ports or on railways, and they are conducive to a maximum spread of development throughout a country, and the early realization of a power grid. Hydro-electric power is also an ideal adjunct to other forms and can be used as base or peak load according to circumstances, provided at least diurnal storage is available. Recent developments have indicated the advantage of pumped storage. Nuclear power, to be economical has to be operated at a steady load and pumped storage or water power forms an ideal supplement, and for this reason is unlikely to be superseded.

Linked Development

The associated disadvantages and limitations of water power are, in general, far outweighed by the advantages. The main advantages are the avoidance of atmospheric pollution and the many factors implied by and resulting from reservoir storage. Reservoirs form a scenic and tourist attraction; the fishing potential may be important, they can be used in conjunction with irrigation schemes, either by providing head or electric power for pumped irrigation. Their regulating effect is of great benefit in flood control, erosion and sedimentation being prevented by reduced maximum flows, and the absence of flooding of the river banks is conducive to mosquito larvae and fly control. The regulated flow below dams and the reservoirs above may make inland navigation possible.

Organization and Finances

1. *Control*

In the past, development has depended upon the initiative of a private company. This has resulted in quick construction and efficient operation. On the other hand, the schemes have been chosen without thought to the optimum development of the country and the possible clash with other interests.

State control would be the logical set-up. On the other hand the civil service has no tradition of over-all economic planning, its constructive efforts having hitherto been confined to communications and the P. W. D. However it should be better able to raise the finance for capital development and to shoulder the attendant risks. Moreover it can ensure that development keeps pace with the needs.

An alternative is a Statutory Authority appointed by the State specifically to control a multi-purpose power scheme. It is better that there should be one such controlling authority than, as is usually the case in the older established countries, several independent departments and authorities such as drainage, irrigation, water and power supply in competition for limited natural resources. In the raising of capital, such a Statutory Authority may be at a disadvantage as compared with the State in the securing of long term loans from external sources.

Another possibility is the private company operating under licence with the State in over-all control. The private company must be given sufficient inducement and guarantees and it does mean that with increasing prosperity there will be an increasing flow of money out of the country in the case of an external private company. However, where there is difficulty in providing the initial finance this is a viable solution.

Catchments involving more than one State require a unified control if there are to be efficient developments. This is one of the most difficult and urgent problems of the day. There is scope for United Nations statesmanship here.

2. *Time Factor*

The period for financial planning unfortunately is a different matter from the planning period for optimum development. It must, however, to some extent, be commensurate with the life of the plant and that of the electrical equipment, 30 years, is approximately a human generation and is probably as far ahead as can be attempted. Having worked out a scheme of optimum development its fulfilment is an urgent matter, as the rate of increase of prosperity of the country will depend thereon. Another reason for early capital development is the continued fall in the value of money. On the other hand the construction programme should be steady and continuous commensurate with steady expenditure and employment. To ensure that consumption of power keeps pace with the maximum rate of development it may be necessary for the State to assume responsibility for new industries, or at least to build factories which can either be sold or leased to private concerns.

3. *Finance*

If at all possible capital should be raised by local issues. Normally, however, an approach is made to the World Bank. This is generally preferred to national loans as being less incompatible with full independence. This often results in the employment of American assessors and engineers, when all necessary work has already been done by European engineers. One aspect of hydro-electric schemes and of public works in general is the advantage of going ahead with construction during periods of depression, thus making use of low costs and cheap labour with the probability that the completed scheme will be ready for production in time for the period of renewed activity following the slump.

Technical Aspects

Increasing economy of tunnelling operations increases the flexibility of hydro-electric plant by making possible the linking of neighbouring catchments.

High-head schemes are generally the more attractive and are conducive to a better geographical spread of power in conjunction with thermal stations. Low-head schemes are usually in the lower reaches and are usually run-of-the-river schemes. Storage is expensive, involving extensive flooding and other problems arising from silting, large and largely unknown flood flows and a sometimes excessive tail-water rise.

Storage reservoir schemes are a particular advantage where a chain of power schemes can be constructed in cascade as the upper reservoir provides regulation for all the lower plants. Construction can also be phased more easily. In many cases there is scope for pumped storage in conjunction with other power schemes. It provides freedom in the selection of a suitable storage site whether for subsequent power purposes or irrigation. Power schemes consisting of multiple units with unified automatic control not only allow for the spread of capital expenditure but also ultimately give a more economic use of the water. With large power consumption transmission over long distances becomes economical.

Construction

Although an immediate start on construction can be made by manual labour, hydro-electric plant has eventually to be got there. Also subsequent operation and maintenance will normally require access roads, in which case properly constructed roads should be made in the first place. The use of a helicopter in inaccessible sites is now a practical proposition. Plant design should take account of transport difficulties. Earthquake hazards should be taken into account in the design of dams. General lack of information concerning maximum flooding necessitates the special design of coffer dams and flood spillways. Embankment dams are being increasingly used and to ever greater heights. These introduce special problems of stability during construction and spillway design. In general designs should take full advantage of the cheapness and immediate availability of local labour.

References

1. *Addison*, H.: Land, Water and Food. 1955.
2. Buffalo Books Ltd. for the Department of Information Services, Gold Coast: The Volta River Project. 1956.
3. *Clements*, Frank: Kariba — the struggle with the river god. 1959.
4. *Cochrane*, N. J.: L. Nyosa and the Shire River. I. C. E. V 18, Dec. 1957.
5. *Cocks*, E. B., and *Pickworth*, C. H.: The hydro-electric developments in territories administered by the Colonial Office. In: Conference on Civil Engineering Problems in the Colonies. 1954. P. 81—94, diagrams.
6. *Coyne*, M. A.: Kariba Gorge and Kafue Gorge hydro-electric projects. (Paris, Nov. 1954), Salisbury, 2 plans.
7. J. East African Institute of Engineers: 1956, 1957, 1959, 1962.
8. *Gay*, L. O.: The geology of the Bui hydro-electric project. 1956, 60 pps. with maps.
9. *Gibb*, Sir A., and Partners, and *Kennedy* and *Donkin:* Owen Falls hydro-electric scheme, Uganda. Project report. Government of Uganda, 1948.
10. Government Printer (ed.): The Kariba Project a brief description. Salisbury.
11. *Halcour*, S. W., and *Pless:* Development of the Pangani River Basin. Report to the Government of Tanganyika. 1962.
12. *Halcrow*, Sir W., and Partners: Preparatory report on development of the River Volta Basin. 1950.
13. *Harding*, S. T.: Water in California. 1960.
14. Her Majesty's Stationery Office for the government of the United Kingdom and the Gold Coast: The Volta River Project. 1956, 3 Volumes, (1) Report of Preparatory Commission, (2) Appendices to Report of Preparatory Commission, (3) Engineering Report to Preparatory Commission.
15. *Howarth*, D.: The shadow of the dam. 1961.
16. *Jeffares* and *Green:* A water resources survey of Basutoland. Johannesburg 1951.
17. *Jeffares* and *Green:* Report, maps and drawings on hydro-electric and irrigation developments of the Great Usutu River, Swaziland. Johannesburg 1955.
18. *Kennedy* and *Donkin:* Karuma Falls Development, Uganda. Report on the Fulu, Lira, Masindi, Hoima and Butiaba Areas. Kampala 1958.
19. Inter-territorial Hydro-electric Power Commission, Central African Council: Report on Kariba Gorge and Kafue River hydro-electric projects. Salisbury 1951.
20. *Krutilla* and *Eckstein:* Multiple purpose hydro-electric development.
21. *Lagus*, Ch.: Operation Noah. 1959.
22. *Legge*, R., and *Robins*, E.: Animal Dunkirk. 1959.
23. *Mitchell* & *Vaugham-Lee* (ed.): Uganda Protectorate, hydro-electric development of the Victoria Nils. 1935.
24. *Mitchell* & *Vaugham-Lee:* Kenya Water Power. Report to the Crown Agents by Preece, Cardew and Rider; and Coode, Wilson. 1935.

25. *Nedeco:* Jebba Project (Nigeria). Feasibility report. 1958.

26. Overseas Institute: Problems in the Colonies. Conference on Civil Engineering. London 1952, 1954, 1956, 1962.

27. *Richards,* E. V.: Water power resources of East Africa. Report to the Crown Agents. 1948.

28. *Roberts,* C. M.: Fundamental economics of hydro-electric development. J. I. C. E. 1951.

29. *Sharples,* J.: A long-term forecast of development of electricities supplies in the Federation of Malaya. IEE, Sept. 1961, Vol. No. 2.

30. United Nations: Water Supply Asia. Multiple purpose river basin development:
    1. Manuel of river basin planning. New York 1955.
    2. a) Water resources development in Ceylon, China, Taiwan, Japan, and the Philippines. New York 1956.
       b) Water resources development in Burma, India, and Pakistan. New York 1956.
       c) Water resources development in British Borneo, Federation of Malaya, Indonesia and Thailand. New York.
       d) Water resources development in Afghanistan, Iran, Republic of Korea and Nepal. New York 1961.

31. U.S. Department of Agriculture: Water — The Year Book of Agriculture. 1955.

32. U.S. Federal Power Commission, 1953.

33. *Zimmermann:* World resources and industries. New York 1951.

34. 5th British Columbia Natural Resources Conference, 1952.

XI. Aspects of Organization of a Water Development Department. Training of Staff. International Co-operation

by L. J. Mostertman

According to the programme organization, training and international co-operation, we are here in a field which is not more strictly technical, but this field relates more to human relations. Before we start discussing the points I have in view, it seems to me a good thing first to devise the aims of our technical assistance and to give a short outline of the big problems of development which we encounter.

As a consequence of the enormous and very fast technical advance and also of the establishing independence of many regions in the world which formerly were colonial regions, we have all over the world a big rush towards technical and social progress, higher standards of living. But when looking to various parts of the world I see very clearly that the needs are not everywhere the same and that also the ideals are not everywhere the same ones.

As to *Asia*, already centuries ago there was a high standard, a high standing culture in times when we in the North-Western Europe were still very much underdeveloped. Nowadays in these countries we see a gap as to the big advance of technology, which is also partly due to the fact that the colonial governments meant a certain stand-still in the development of the people itself. We cannot say that these countries are underdeveloped in a strict sense, but we see an enormous abundance in population causing big difficulties in getting in the country so many investments that the rate of investment keeps up with the rate of cost through greater population. They are not in the first line asking us for a new line of thinking nor for a new culture but for material help and technical assistance where we can give it.

Africa gives quite another picture. Here the population is essential rural or cattle breeding farmers, these countries have become independent, looking to overcome the difficulties of organizing small tribes into one nation and trying to find for each nation its own personality. These peoples are looking now for a new culture. They are very much in need of technical and capital help, which for them are not only means of getting a higher standard of living but also means of creating a new pattern of life.

South America has been penetrated by settlers from outside, only those hold of that country rather imperfectly. A small class has in hands the means of production of the Government, take part in the Government. Here many factors of social and economical character have to be overcome in our development aid.

As we are giving development aid to these different peoples, we in the first place must think of what the needs and ideals of them are, not forgetting the fact that these peoples are to find their own way of thinking and so we must depart from the fact that there are already existing ideas as well as very old methods in water supply so our help must be adapted to the needs of the people. Added hereto come the difficulties from the system of education and training, the colonial governmental pattern very often has been followed by the independent governments and such we find British, French, Dutch and Spanish patterns.

Now speaking about water development. We heard it during the last days very clear: water has different uses. In second line the water development, the meaning of water development differs, may differ very largely between the various countries. Perhaps we do as engineers overrate the importance of water development. These two factors do actually determine the organization of water resources development. The first line, the very competing uses as considered the existing, the traditional services for spending and dealing with water are very often very different. When we look at meteorology, this is also necessary for air transport, sea transport and in many countries elsewhere. We see the same for hydrographic services preparing sea charts, river charts. The groundwater surveys are very often in hands of the geological department, the water supply very often in hands of the Department of Public Health.

Waste water sometimes belongs to the Department of Public Health, sometimes to authorities responsible for the channels respectively the rivers. Rivers sometimes are governed by a general public department, sometimes a means of conveying in navigation.

Each country has its own pattern. In Germany the waste water is basically in hands of two Ministries, Public Health and Transport. Very much has already been said about the ideal organization and ideal co-operation between all these organizations. In countries which are going to develop in first line one would say: let us unite everything with water in one department. If we try to do so, we may overrate the importance of water on account of other means. In *Egypt* we find a very good meteorological and hydrographic service, which are independent but working together. I do not think that really a standard solution can be found.

In developing countries where water is very important, there is, however, a strong need to have one body that takes care of all these water needs. Very often this body is named "Water Board" but I want to give a warning that if you hear "Water Board" you have to realize that not in all countries the same thing is meant with such an institution. Sometimes it is an institution on the level of Cabinet Ministries, in other cases it is a much wide body comprising representatives of Ministries, the public, the political parties and experts, and sometimes it is purely a Committee, sometimes an entire organization with many engineers.

It is very good to have a powerful Water Board, but we must take into account that a Water Board is not the national planning board, water may be important, there are other issues, these things ought to be dealt with by national planning boards which are on a high level. The Water Board must not become so powerful that it tells the National Planning Board how this body should go on. There must be a supervising institution.

We have various times spoken here about the implements of water development plans. I think that one of the main tasks of a Water Board lies in the field of public relations. It must make this national plan a real public national issue by explaining to the public what has to be done and the big national interests that are beyond these major works. Later-on, on a lower level this will help considerably in the implementing of the national water plans. The third step, very important in the implement of all water plans, is the part taking of the regional and other local authorities. If a water plan must have success, we must ensure as much as possible the co-operation of the population on whose behalf the water plan is made. This can occur very well via the local and regional authorities.

Take for instance *Cameroun*, the villages are very weak, the people have not so very much insight, not much power, it is really necessary to interest the local communities in the thing. This is also depending from the social system, the ideals. I think it important to give the population a saying through their local authorities. In small villages it is not the same as in big communities but in the field of interesting people in water supply, water pollution, the help of local authorities may be very important. The local authorities ought to know the individual interests and needs of the people and take care of the safeguarding of their rights. If by general measurements some rights have been taken from the people, it ought to be explained to and through the local authorities. In many cases it will be wise to hold public hearings.

In some countries we find that the structure of the community is such that it does oppose to such a solution. A few people have all powers, all rights already having been used on their behalf. Then other measures ought to be taken, the matter of the policy differs in each country.

When preparing water works, water resources planning works, there is another important way in which we need the local population. If a patch of land is improved by irrigation, flood control, water supply, that population is expecting to reap the harvest of it. But they are badly lacking of capital and marketing facilities. In such cases agricultural, financial assistance services, co-operation associations on behalf of marketing and credit through local banks are very important.

In *Indonesia* there is traditionally a big tendency of mutual help, there everything is very favourable for agricultural co-operation and for credit to the people.

Engineering Department

Sometimes the engineering department forms are a part of the Water Board, sometimes not. However it is, the engineering department has a big prestige, should have it by the behaviour of its personnel, its knowledge, but it must refrain from trying to be the policy making body. Also from trying to exert immediate pressure on the legislation. "Muddy waters" are the consequence where this does exist. The engineering department should strive to this position by its own pattern, not trying to abuse the fact that it can give to this or that man a feasible water right, but its aim ought to be position of the community.

The foundation of a Water Board and an Electricity Board sometimes takes considerable time. The first step to be taken by the Water Board should be the setting up of a legislation. There is no other way of doing this before the Water Board is actually founded. For a first Water Board opportunity should be made available by the Government giving the future executive board the possibility of taking provisional measures on behalf of the land and water resources. Otherwise in the meantime valuable water and land resources may get lost, soil speculation can occur, haphazard measures can be taken which damage the all-over planning seriously. One of the biggest aspects of the Electricity Board are the engineers. Speaking about them brings into view the difficulty that when using the word "engineers" not in all countries the same men are meant.

Let me give a very clear example: in the *U. K.* they give the boy a very good secondary school education, followed by an Engineering School of 3 years, forming the base. The man becomes an engineer by working some years in practice being supervised by a recognized engineer. During this period he matures and afterwards he is admitted to an institution of engineers. He starts then with doing relatively simple technical work, climbing up until he lands somewhere towards the end on a high level.

In *France* we find a very long and intensive training, going very deep into the fundamentals, also in the mathematical matters. There he is not the man on whom the work in progress really depends, for this purpose there are second-level engineers. The highest man starts going around the work, studying the difficulties, the from day-to-day work is in hands of other people. Later-on, the engineer lands on a high administrative responsibility.

These systems have gone on in the developed countries. They do not work so well in the colonies. The British have succeeded in giving to their engineering standards a certain level which are recognized and respected as well. People take bachelor's degree, after that time the British engineer is supposed to have transferred his knowledge from the older one to the younger ones. This is not possible in the developing countries. The older engineers are not there, sometimes they are working in politics or business. There is one danger inherent to this system: if the education of engineers goes on, then too many engineers are coming for the country causing a very bad lack of engineering experts.

As to the french system, this also has a very big disadvantage. The top people have to meet very high requirements. Only very few men of the developing countries reach these standards. When they get back to their own country, they form a kind of a cast but there are too few of them. Below them is the class of secondary engineers, again consisting of too few people. This causes many difficulties.

We must try when speaking of engineering education to lead it so far that the countries find their own systems, which must not too much differ from each other, they must remain comparable. This means a very big task for the UNESCO. *India* and *Pakistan* have already undergone considerable evolutions, they started to leave the British standards and established a very severe system of guidance to studies and of residence and then may give a man quite a lot of responsibility, people advance excellently.

There is of course also a need of a higher level training, of preparing specialists. In *Germany*, when a man wants to become a certain kind of specialist, this is quite easy, he goes into the service of the specialist, works with him, gets the skill and becomes a specialist himself. In developing countries this is very difficult, sometimes the specialist to work with is not there, the country cannot afford to wait for years until the engineer has got the specialized skill. So we need specialists training as well. This can be given in various countries, one of the best ways is concentrating in regional areas. So we find a course of the Seattle University in Bangkok as well as another American course in Lima, Peru.

These courses can last from a few weeks to a couple of years. They must give up-to-date information, immediately applicable on projects going on in that region, to the engineers who have finished their courses elsewhere.

Now I want to make a general remark: the aim to developing countries is for us not only an action in one direction, by the study of the developing country we ourselves can learn very much. We also are subject to very important stresses due to the advance in technology, due to political and social issues. This makes it necessary for us too here in Europe to keep up with things. Formerly an engineer graduate was ready for the next 20 or 25 years. Since the last war the advance in technology was so fast that this preambule is no longer in force. It takes a man 2 or 3 years for learning how to handle the biggest computers, the machine only being in action for 5 years. There is a tendency to give the post-graduate courses also in our own countries. This may be very useful for our own needs.

Training of engineers and experts for the developing countries is also very often given abroad, in Europe and in the States. This is mainly due to a factor of prestige, especially important for Pakistan. Now we see more and more that the Africans want to be educated in their own universities, they like to become an African personality. Preference is given to the African-breeded people as well. But we do not only need engineers, we also need operators, draughtsmen, technicians and there is a general feeling now that these people ought to be educated in their own countries or regions. The needs for the underdeveloped countries are not yet been filled, this can be happening in the forthcoming years by people from the own countries trained there. Very often we find in the country itself the man who can do the job very well. There exist very many histories about experts: difference between short-going and longer time going people. As Mr. de Vajda already stated: the expert is a man who is far away from his home. And this is quite so.

When looking after the properties an expert should have: not only look on the subject, the man who is the best expert in his field at home is not always the best one in other countries. First of all is needed a stable personality, though however not too stable, taken into account the possibility of getting frustrated. On the other side he must be not too rigid, not sticking too fast to his own principles. This is only one of the important things. Another important thing is patience, you sit and eat whole days with the local people but when people ask you something which you promise to do, you ought to do it yourself without your ideas upon other people. It is not very easy finding such people nowadays. When sending out a man you must make him free of his work; perhaps the payment can be a bit higher but there is no safety as to work and position when coming back neither as to the possibility of getting another assignment. The U. N. must try to overbridge this gap. It is a very difficult problem.

I think that here lies a very important task for our Western countries. Our administration should have some extra places where we can have a man or have him not and we must have a possibility to send out a man and give him the guarantee that when he will have come back, he will come again with the same anciennity as he would have had when he had remained in his position. We in Holland are now having some extra procedures, in Delft we have a few extra professors. I think this is a very important way of helping other countries to get the experts needed. Very often the question is put: which way of working is better, sending out individual experts or a team of people belonging to the same institution or to a big engineering firm or a laboratory.

In first instance we have had excellent results in *Nigeria* on the Niger project when we sent out a rather large team. Some had a chance of staying on in the Nigerian civil services, some did and also the Nigerian reviews have been excellent but the follow-up has been neglected completely. Working with such a close team is very difficult, to come to a good follow-up. The same applies to consulting engineers.

We are therefore considering another procedure: make mixed teams consisting of a number of people, also of young Dutch people from initial courses and add to it some people from the aid-receiving country. Give at the same time a special education to the very specializing people of the developing country who are to follow-up the project. Gradually replace the foreign people by inhabitants and if necessary give post-graduate courses to a few selected engineers. It often happens, however, that when you did train and specialize a man who does his job excellently, the relative Government shifts him over to another department.

Now as to international co-operation. I have already mentioned the ways of giving help to the developing countries. The first way is: give as much as possible aid and assistance via the U. N. organizations and agencies which are already existing. The second way: the research is in our own hands on behalf of the others, taking into account however, that for instance very many hydraulic investigations are very much alike. For the Niger project many laboratory investigations had to be made. We made a pilot project, bring over Nigerian engineers to work on it, have them build in their own country a shed for making models, give a good follow-up and let them walk alone as soon as possible. Another way is teaching in specialized courses, such as the International Course in Hydraulic Engineering we are giving in Delft. The half of the participants is from the States and Europe, especially made up for the under-developed country. It is also very important to overcome the stresses caused by the advance in technology and political and social issues in our own countries.

XII. General Principles of Water Legislation at Different Stages of Development

by H. P. Michael

The decisive step towards greater production coincides everywhere with a rapidly increasing demand for water. In tropical and subtropical areas with their long dry periods, high rates of evaporation and insufficient artificial storage additional requirements due to urbanization, irrigation and industrialization quickly exhaust surface and groundwater reserves and create catastrophic supply situations which cannot be met by administrative and technical improvisation alone. Economic aid projects have lost much of their social and economic dynamism where by virtue of the existing laws the water resources cannot be marshalled in the public interest.

Modern water development in a developing country demands the firm establishment of three institutions in its water code:

1. *A strong water department or statutory body* which in the field of water affairs carries out the integrated social and economic policy of the government. This department establishes and maintains an inventory of all water resources as well as of present and potential uses; it administers the water laws and controls current uses, takes initiatives regarding all development projects and discourages damaging and dangerous practices. It is a motor for a progressive water policy and needs farreaching legal powers to put its plans into practice.

2. *An advisory council on water affairs,* recruited from representative sections of the public. In tropical and subtropical countries major decisions on water frequently impose heavy sacrifice or restriction on some members of the community. Hence the public must be satisfied that at least the principal technical, legal, administrative, economic and social aspects have been discussed with independent experts and the vested interests before major new water allocations, particularly unpopular measures of some consequence or departures from the hitherto proclaimed policy are put into practice. This advisory body would create the necessary atmosphere of confidence, yet cannot claim to be a water parliament and hence does not interfere with political responsibility.

3. *Legal provisions* adapted to the requirements of up-to-date water development practice and giving to the government ultimate control over all water resources. This may mean the final departure from traditional doctrines of the former colonial powers, viz. the "riparian principle" for surface waters, the rule of "unlimited use" for groundwater, both doctrines which in local variations have been adopted from the Common Law. It may mean departure from simplifying water ordinances and from traditional tribal practices. It is essential that government control over groundwater and surface waters is absolute; and that the promulgation of the water code cancels all previous laws and ordinances by virtue of which it may have been previously possible to acquire water rights or licences, or exercise direct control over bodies of water; it means that the traditional connection between land property and water rights is severed and the practices of lumping together mining rights and water use as well as factory permits and licences to discharge polluted effluents discontinued. In water-short countries or in such areas where industrialization will create shortage in the foreseeable future governments are tempted not to be satisfied with control but demand that all water be vested in them; renewable permits greatly simplify the position of the government, but are not particularly attractive to private enterprise.

Where developing countries are in a position to make a complete breakaway from tradition, the consequences of the decision as to which system ought to be adopted — a system of long or medium term water rights, of temporary allocation or a mixed system — go far beyond the scope of a water resources policy and touch complex and delicate economic questions, viz. the future of private foreign investment. Ultimate priority for the public interest over the interest of individuals demands, however, that established rights must be respected and expropriated only against fair compensation.

The legal provisions enacted in the water code should be as flexible as possible and give the widest possible discretionary powers to the water department; the establishment of generally applicable priorities by law has proved everywhere to be a severe handicap to economic development.

Several tropical and subtropical countries have promulgated in recent years progressive water laws; the United Nations Conference on the Application of Science and Technology in Underdeveloped Areas has produced a number of stimulating papers on problems and achievements of water laws (Turkey, Israel, Egypt, the Sahara, Mexico); furthermore, a vast, most instructive literature on such matters has developed in overseas countries which — as former colonial territories

— took over from their humid mother country climatically unsuitable legal doctrines of the pre-industrial age and had to struggle almost a century to cast off this dubious heritage (Australia, South Africa, the Western provinces of Canada, the Western states of the U. S. A.). A schedule of the more important provisions for groundwater — yet without any qualification — is given in a recent U. N. publication. A similar catalogue for surface waters can be prepared without difficulty and serve as raw material for future water codes in developing countries. Yet it is to be doubted, as to whether the drafting of detailed model water laws would serve any useful purpose as the political, social and economic circumstances vary from one territory to the next. It is, however, quite conceivable that for a region a general section of a water code could be developed into which the basic principles which apply to all neighbouring countries could be incorporated. Every territory would — subject to its peculiar customs, traditions and state of economic development — produce its own provisions in addition to this general part and set its own accents. For the countries of Africa South of the Sahara an arrangement of this kind would probably be perfectly feasible in spite of their different stages of economic development.

The general lay-out of numerous basic provisions could be common to all: a section dealing with duties and powers of the water department (the duty to prepare hydrological and legal inventories of catchments, to establish and maintain measuring devices and evaluate their data, the power of inspection, of constructing water works of any description, of sinking boreholes, etc.); sections dealing with the establishment of protected areas, with the control of pollution, with the procedure of applying for and granting of water rights and permits, with the control of abstractions; a penalties section, dealing with water offences (for waste, for taking more than the allocated share, for irrigating at non-authorized times, for polluting beyond the permissible, for putting up obstructions in the river or in the flood plain without a permit, etc.).

It is obvious that provisions for an economically more advanced community, viz. on water boards, on detailed administrative procedure for effective pollution control in an industrialized area, etc., should be omitted in the water code of a country which will not have to cope with such problems for many years to come. Yet the general legal frame must be set now and a water Department — small as it may be — put to work. For the different stages of economic development the frame established by general provisions of a water code should be the same; the filling up can be different in volume and in the substance.

How can we convince developing countries that a progressive water code is a prerequisite to water development aid, and indeed to any kind of large scale economic aid taking its full effect? As a rule, all governments favour water legislation on the lines suggested here. It strengthens their hand and serves as a useful tool for economic and social planning. Yet in numerous developing countries vested interests are politically influential and would mobilize powerful resistance in their defence. Many a government may, therefore, welcome gentle pressure exerted on it in this respect during negotiations for an aid agreement; a demand for the enactment of effective water legislation put forward at the appropriate moment will rarely be turned down by the representatives of a developing country.

Much attention has been focussed in recent years on the status of international rivers and much effort has been invested in attempts to persuade riparian governments to conclude international agreements on the joint development of water resources in such catchments. In tropical and subtropical regions the absence of co-operation leading to mutual agreements must cause loss of economic and social opportunity on a considerable scale. For developing countries a particular reason should favour early negotiations: there is the danger that riparian countries at a less advanced stage of economic development arrive too late to stake their claim, and it is always difficult to repair the damage and to deprive another country of water benefits which it has enjoyed for some time and on which its economy has been built. A first step towards the settling of disputes on international rivers is the setting up of common hydrological survey parties. The help of the U. N. and its agencies for the timely negotiation of international water agreements in developing countries is to be welcomed.

References

1. Numerous recent water codes of developed and developing countries.
2. *Caponera*, D. A.: Water Laws in Moslem Countries, FAO Development Paper No. 43, Food and Agriculture Organization of the United Nations, Rome 1954.
3. *Sikes*, H. L.: Modern Water Legislation, P. W. D. Nairobi, Kenya 1922, with numerous references.
4. *Kanthack*, F. E.: Industrial Development in the Union of South Africa in Relation to Water Resources, Associated Scientific and Technical Societies of South Africa, Johannesburg 1946.
5. *Sutton*, W. G.: Water as a Basic Factor in the Development of the Natural Resources of South Africa. Associated Scientific and Technical Societies of South Africa, Johannesburg 1952.

6. United Nations Water Resources Development Centre: Large Scale Ground Water Development, United Nations Publication 60. II. B. 3. New York 1960.
7. United Nations: Integrated River Basin Development, U.N. Publication 58. II. B. 3. New York 1958.
8. *Virshubski*, M.: The Role of Water Legislation in a Developing Country, U.N. Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas. Geneva 1963.
9. *Gosselin*, M.: The Adaptation of Water Legislation to Changing Conditions: A Proposed Code of Water Laws for Under-Developed Areas Particularly in Arid Zones. Geneva 1963.
10. *Karatekin*, N., *Akyurek*, O.: Adaptation of Water Laws of Turkey to Changing Conditions and her Bilateral Agreements on International Streams. Geneva 1963.
11. *Langone*, A. R.: The Latest Statutes Governing Water Resources. Geneva 1963.
12. The Department of Economic and Social Affairs of the United Nations: Approaches to Water Resources Development in Developing Countries. Geneva 1963.

D. Annex

Recommendations and Findings

Introduction

Water Development as a Part of Foreign Aid

A water development will be an essential part of any foreign aid effort which seeks to promote economic growth and is responsive to the social aspiration and political realities of less developed countries.

Clearly it has a major share in the public investment programs of most of these countries. In the Indian five-year plans water development, including irrigation, power, flood control and community water supply, has accounted for from 20 to 30 per cent of the total investment. It amounts at least to 25 per cent in the first two five-year plans for Pakistan. Among the 15 nations for which International Bank Teams have recommended long-term investment programs in recent years the expenditures proposal for water ranged from 3 to 42 per cent, of the total, with all but three of the national programs allowing more than 13 per cent.

Its importance should not, however, be gauged solely by its share of public expenditures. In some countries where agricultural production is crucial to future growth or where it provides needed foreign exchange the extension of yields from irrigated or drained lands may be absolutely basic to improvement. Even in some countries, such as those in the Mediterranean area, where long-term industrialization is the aim, irrigation and land reclamation may play a key role in providing for increased food needs during the transition period. Hydro-electric installations may be vital to meeting energy demands from industrialization. Although relatively small in total costs, community and rural water supplies may be required to improve the amenities and build the health of growing populations. In some countries large water projects have become the symbol of heroic efforts to raise levels of living and to enrich the quality of human life.

It nevertheless would be a mistake to think that every water project is automatically good. A few cases can be cited to show that it can be designed poorly and that its contribution to national advancement can be disappointed. Knowledge of such experience does not detract from the importance of new water programs, nor is it likely to discourage strenous efforts to finance new projects. Rather, this growing experience points to lesson which helpfully can be applied to reviewing future aid programs.

The role of water development may change radically with the economic advance of a nation, and it is not practicable to give any other general rule than that the type and scale of water activity should be related to the special needs at any given time. At one time preference may lean toward labor intensive projects and at another stage to capital intensive points. Improvement or maintenance of food production from already irrigated land may take priority at one period, and creation of new crop land at another. Basic surveys may be of first order for one region while massive construction is indicated for another. The urgency of gaining new income may favor small programs with early returns over larger projects which will require decades to complete.

I. Water Development in Less Developed Areas

1. The urgency of water development in less advanced countries has to be accepted and taken into account. The pronounced symptom of underdevelopment is a large rural overpopulation, not employed. This has to be absorbed by developing water resources wherever possible. The aim of the development must be to increase the income per capita in countries with large population. The tremendous increase of population will gobble up all the savings due to development unless the pall of development is more than the rate of growth of population.

2. The policy of aid programmes must be based on strategy designed to bring the poor nations to take off in a shortest time. The socialistic urge in the less developed countries has to be noted and the aiding country should not lay emphasis on private investments as chief instruments of economic development.

3. The aiding country has to set up an organization to obtain quick and reliable information about the projects. Smooth procedures in negotiations must also be developed.

4. Water development structures, such as dams, canals, wherever they are built, are based on the same principles of design. Only in details there may be differences. Engineering handicaps, such as want of hydrologic data, absence of laboratories, specialists, will tend to

increase the costs and the increase has to be met with by achieving economics through utilizing local materials, such as the use of stone masonry instead of concrete, and adopting earth dams wherever possible.

The construction plant layout and technique has to take into account the local conditions and availabilities of cheap labour, etc.

5. In countries like India and Pakistan, there are well organized engineering departments which are capable of utilizing the aids profitably. Where such organizations do not exist and where any suggestions to ensure effective utilization of funds are found necessary, they should be made, and the receiving country must accept the suggestions.

6. The gap in the technology between developed and underdeveloped countries is greater and more impressive than the inequality of *wealth. For execution of works, engineers, technicians and craftsmen* are required and training programmes have to be carefully worked out well ahead of undertaking the projects.

7. In less developed countries, rivers are veritable treasures and must be fully exploited. Five types of beneficial use are possible:

a) Power
b) Irrigation
c) Water supply
d) Navigation
e) Flood control

Where the population is large and country is deficient in food, assistance to irrigation schemes will be greatly welcomed and will earn a lasting goodwill for the aiding country.

Power projects are always profitable and can be considered for aid by capital investments.

In water supply and navigation schemes social advantages are great, but as the returns are small they are best financed locally and only foreign exchange, technical assistance and grants may be considered for aid.

8. For less developed countries, foreign assistance is inevitable. As the country develops and till it reaches a take off stage, the requirement of foreign exchange will increase. So the developed nations of the world will be faced with the problem of assistance for many years to eliminate the low standard of living and poverty from this world.

II. Criteria for Review of Water Programs

1. In the technical recommendations which follow we suggest a number of points which deserve emphasis in considering new proposals for work outside of Europe. These are arranged by major aspects of water study or management. Certain other criteria brought application to all aspects of water development and are outlined here.

2. It is desirable to arrive at some judgement as to the degree to which any water proposal is related to broader national aims. It will help to recognize what is known about the place of water programs in the national effort by asking the following questions. This may be difficult either because national plans are lacking or because studies are incomplete. Rarely will either be entirely satisfactory, but decisions will be made in the face of gaps and uncertainties at many points.

a) Are the aims and design criteria stated explicitly?
b) Does it canvass other means than water development to reach these goals?
c) Does it consider alternatives to the conventional engineering measures?
d) Are the necessary complementary measures included?
e) Are fiscal limits recognized?
f) Does it specify needed institutional changes?

It is common to speak of water programs being "justified" or "economically feasible" within several different frameworks.

3. *Financial criteria,* such as those used by the International Bank or commercial bankers, can be applied to determine the prospects that some part of the investment will be reimbursed over a given period at a given interest rate. The procedures are well known and straight forward. They may sometimes lead to unexpected results because they tend to ignore or minimize impacts which do not directly affect cash income and repayment. Oftentimes, the indirect social costs of an undertaking are minimal, and disappointment follows after the project is underway.

4. *Economic criteria,* such as those specified in UN and ECAFE publications call for a wider assessment of indirect and intangible benefits and costs from water undertakings. Benefit-cost analysis when carried out with care and comprehension can suggest the broad effects of water development upon future streams of benefits and costs. It can take account of and seek to assign some value to all changes in productivity whether or not the value can be taxed or

recovered by fees. It thus canvasses numerous impacts, such as destruction of scenic values, stabilization of village life by health measures or prevention of catastrophic, dislocations from floods, that would not figure in a financial analysis. Even where precise amounts cannot be given to these effects they can be noted and their importance can be described. It is not unreasonable to expect proposals to be accompanied by a rough economic analysis in which the following points are stated explicitly:

a) Discount rate
b) Time horizon
c) Economic and social aims
d) Method of estimating benefits
e) Method of estimating costs
f) Decision criteria

The detailed methods may well vary with national circumstances. Many economically feasible projects are not financially attractive in terms of direct repayment.

5. *Other criteria*, such as those which finally influence a national budget allocation, may not emerge in the economic analysis but may be decisive. Perhaps the two most difficult problems in review of water development proposals center on a) the urgency that is felt in low income countries to get mayor works underway, and b) the enthusiastic commitment that grows up around particular projects which have reached the final design stage. Aims of social reform, of preventing social distress, of building up the tone of community life, may dictate action that does not meet ordinary financial criteria.

6. We suggest the following as being helpful in dealing with the enthusiasm and pressure that builds up in these situations.

a) It often is preferable to begin with smaller projects or elementary stages of larger projects without prejudicing ultimate base development rather than embarking upon the larger projects at once.

b) It may be more economical and speedy to hold up decision until desired surveys are completed than to move ahead hastily with construction.

c) Although action on project usually is seen as being either negative or positive there often are other possibly attractive alternatives for constructive action. For example, there may be opportunities for needed surveys, for training of required personnel, for research on new techniques, and for extension work. Sometimes one of these measures may promise earlier and large returns than capital investment. Wisdom in the choice of the most fruitful type of program at a given time is at the heart of a sound aid effort.

7. After all of the financial and economic analysis has been carried out, other considerations may strongly favor — or raise doubts about — proposed development. These reflect the solid lessons which have emerged from the far flung water management activities of recent years.

To take these lessons into account is not to counsel perfection which no less developed country can satisfy. It is to be aware of difficulties which may be averted and of opportunities which can be sized for the benefit of all concerned. Precise answers to all the questions which should be asked cannot be expected. Awareness of the really critical questions and of the experience they reflect should characterize an aid program.

III. Cartographic Data

1. It is recommended to make the most possible use of already existing air-photography and terrestrial photography.

2. If new flights are planned for any purpose, the requirements of the hydrologists, geologists and soil and land use specialists, should be taken into consideration with regard to scale, flight height, extension of the overflown area, etc.

3. Air-photos should be differential rectified. These ortho-photoscopic pictures transferred to the right scale, can be taken into the existing maps without any auxiliary construction.

4. Systematic comparisons between repeated flights made at different times at shorter or longer time intervals should be regularly studied to recognize changes in soil conditions, vegetation, agricultural use, etc.

5. If good topographic maps are not yet available, air-photography should be used to greater extent to prepare a topographic map to be used as base for statistic and topical maps.

IV. Geology

1. The influences caused by the general geological frame of a landmass and its structural belts should be taken into due consideration when planning great water engineering schemes.

2. Safe construction of dam projects necessitates a close adaption of project layout and remidial foundation treatment measures to local geological conditions and earthquake dangers.

3. The changes in geological evolution trends and changes in the intensity of such processes caused by the incorporation of a section of the crust of the earth in the construction of a dam and a reservoir should be predetermined by geological and pedological investigations and are forming a part of the project.

4. Combined hydro-geological and geophysical investigations for the development of groundwater resources should be carried out by a working team, the smallest unit of which is formed a hydro-geologist, a geophysicist and a technician.

5. The outfit of the team should, besides a chemical field laboratory, consist of a geoelectrical and a seismical equipment.

6. The pedological research of the preconditions of the development of water resources forms a main part of such planning.

7. The establishment of research stations in projected irrigation areas of the arid and semi-arid regions will be necessary to prove by tests the suitability of the existing soil and water. The results of the tests will provide the base for a final land classification.

8. In irrigated areas by careful measurements the fluctuations of the groundwater level and its changes caused by irrigation as well as the changes of the chemism of the water and the soil have to be controled. Drainage measures have to be planned according to the obtained results.

V. Community Water Supply and Sewerage in the Developing Countries

1. It is estimated that about three-quarters of the world's present population of 3,000 million is without a supply of drinking water that is reasonably safe or adequate. An even greater part of this population disposes of its excrement in a primitive and dangerous manner.

2. One effect of this condition is the continuance, especially in the developing countries, of a high incidence of enteric diseases which affect three out of every four people, which accounts for about one-half of the total illness and death and which is the major factor in the tragically high infantile death rates in many countries.

3. The supply of wholesome water for cleaning and other household purposes and the sanitary disposal of human wastes have been formed to have great effect in reducing the incidence of diseases that are not themselves water-borne, as well as in raising the standard of living and inspiring human dignity.

4. In the vast rural areas the task of gaining water to support life is an arduous one that falls to the lot of women, and it frequently occupies most of their time. It is ironical that the substance for which they work so faithfully is often the vehicle of disease and death.

5. In addition to its direct health benefits, a clean and adequate water supply, coupled with a sanitary system of drainage, has been found to have a direct and important effect upon its economic and social development of communities. In their urge to reap the benefits of industrialization, many of the developing countries are disposed to all available funds to the building of industry, to the neglect of its most fundamental infra-structure.

6. For all these reasons, the provision of clean water to its people, and the sanitary protection of present and future water sources, should warrant one of the highest priorities in the planning and use of water resources.

7. Due to the universal and pressing problems of water supply and waste disposal, the high degree of acceptability of these services and its relief that can be dramatically afforded within a short period of time, programmes of aid in this field should find favor both with the countries giving assistance and with those receiving it.

8. Although much satisfying water supply and sewerage work is taking place in the developing countries, the rate of progress is usually only a small percentage of the rate of population growth. The vast back-log of deficiency remains untouched, and the situation grows progressively worse. This trend must be reversed by accelerated action if dire consequences are to be averted.

9. Due to the combined effects of vast population growth, urbanization and industrialization, it will become increasingly difficult to conserve sources of water suitable for domestic use. This emphasized the pressing necessity for wastes treatment, the conservation of stream quality and the adaptation of far-reaching policies and programmes in water pollution control. The developing countries should be advised and assisted to protect their water resources before it is too late.

10. Here is the possibility in the developing countries to modify certain existing technical standard for water and sewerage systems

and treatment works in the interest of economy without danger to their performance or safety. Embellishments and luxurious equipments can be dispensed with and savings can often be made in adapting plants to prevailing climatic and labour-supply conditions. Where money is scarce, these facilities should be designed to provide service to as many people as possible, rather than to give perfect service to a few.

11. However, the main problems in this field are not technical, but are of an organizational, administrative, political, managerial or financial nature. They often constitute unexpected and difficult barriers in the developing countries, and assisting agencies may often be more helpful in solving these problems than in providing either engineering or financial aid.

12. As revealed in many developing countries which have made substantial progress in water supply and sewerage construction, these are always woeful deficiencies in operation, maintenance and business management. This causes works to fail to perform their expected functions, plants to deteriorate rapidly and the department to become bankrupt. It is worse than folly to provide costly works unless suitably qualified personnel can be made available to care for them.

13. No facility in these categories should be presented as a gift to a developing country. The receiving country should participate actively in all phases of the project, in investigations, planning, designing, construction, operation and management, and should bear a substantial part of the financial burden. Moreover, no project should be undertaken in this field which does not involve the development and training of personnel in the various categories of duty which will be involved.

14. It should be borne constantly in mind that in giving aid to a developing country it is not the mission of the assisting country to rebuild that country, or even one feature of it. Instead, the purpose is to assist in such a way that the developing country may be inspired and helped to carry forward its own programme of development into the future. Close partnership between the two countries is essential if the project or programme is to achieve its real purpose. This purpose is regeneration. Whether it has the element of regeneration should be the final test of every undertaking.

VI. Hydro-Electric Development

Technical Aspects

1. Flood hazards are particularly great and must be dealt with in design and construction.

2. Design should allow fullest use of labour and local materials.

3. Plant and machinery should be transportable, and roads which will be permanent constructed initially.

4. Storage schemes are usually necessary in the full development.

Policy

5. As hydro-electric power may be the key to development, a land utilization plan for the whole catchment should be sketched. There should be a single planning control authority set up.

6. The apportionment of water between power and irrigation must be decided.

7. Hydro-electric projects should be given a certain priority because water is a non-wasting asset and because of the many associated benefits. There are advantages in combination with other power sources.

8. An immediate start on power provision on a small scale (conformable with subsequent development) is desirable. Associated user works should be constructed concurrently.

9. Capital expenditure up to the limit of absorption is desirable in the country's interest. It should, however, be regulated to give continuous steady employment over a long period.

VII. Irrigation and Drainage

1. Irrigation and drainage projects require the continuous participation of large masses of the rural population. Design and operation has therefore to be adapted to the existing conditions and available skill to a greater extent than in other hydraulic works; in spite of the fact that basic technical solutions are essentially governed by physical factors and will be similar in highly advanced and developing countries.

2. In view of this intensive participation of the local population, simpler solutions should be given preference whenever efficiency can be maintained.

3. Local labour should be used as much as possible if available both during construction and operation instead of mechanical means to provide employment for surplus labour. Local materials should be used to save foreign exchange.

4. The great difficulty in designing irrigation and drainage work is that in most cases economic returns from projects are not sufficiently high to justify expensive solutions and at the same time structures must be strong to compensate for generally poor maintenance and operational practices.

5. More consideration should be given to smaller new projects and to the improvement of existing systems as it has been done in the past in a number of countries.

Such projects have the advantage of yielding early results and not requiring large expenditure for infrastructure.

6. As a result of pressure for immediate implementation preliminary surveys are often neglected, causing faulty design. Much more attention should be given to soil investigation. The project should not be started without an adequate feasibility study. For this purpose investigations into land use, agronomy, socio-economic conditions and the possibilities of creating cooperation and credit facilities need to be carried out simultaneously with the technical surveys.

7. A deficiency most common in irrigation projects in arid and semi-arid regions is the lack of adequate drainage, an omission causing serious salinity and alkalinity problems, difficult to repair. Field irrigation and drainage systems are often missing in the original design and are left to the farmer who has neither the knowledge nor the means to build them properly. The same applies to land levelling, so important for the economic use of water and higher yields.

8. All these and other deficiencies are due mainly to the absence of well-organized irrigation and drainage administrations, manned by competent and sufficiently well paid permanent technical personnel. Relations between the various subject matter specialists are often not clearly defined. This is caused partly by lack of coordination between various Government departments concerned with irrigation and drainage schemes.

9. These deficiencies make themselves felt even more on the operational side. Several methods have been tried, such as operation through Government departments, autonomous and semi-autonomous authorities, farmers and concessions to private companies. This last can be considered as a good temporary solution, especially if it is con-

nected with training and if a take-over by a local administration can be ensured at an appropriate date.

10. The incidence of bilharziasis has increased considerably in a great number of countries as a result of recent irrigation development whenever no adequate measures have been taken for its control. It has become a serious threat to public health.

Every effort should be made to build and maintain irrigation works in a manner to prevent snail breeding and no irrigation scheme should go into service without an accompanying programme involving the various measures to prevent infection and spread of this disease.

11. There is plenty of scope for useful foreign aid needed during the difficult stages of development. Such aid is needed in the form of foreign experts, training of local technicians, supply of equipment and also as capital assistance.

However, foreign assistance needs much better coordination than it has at present, where very often competition and duplication reduces efficiency.

VIII. Recommendations on Flood Control

1. The river basin should be treated as an entity, irrespective of national boundaries. Aid agencies may be helpful in promoting collaboration among nations sharing the same basin. Aid for such international co-operative projects be given a very high priority.

2. As much data as possible will have to be collected before the works start. Special care has to be taken for long-term variations caused by change of sea level with respect to land level, silting or scouring of the river bed and change of the river's base level.

3. Estimates have to be made of the value of the property to be protected, taking into account the possible increase in the investments and the value of the complementary works undertaken in conjunction with the flood control project.

4. Before dikes or dams are built or raised other measures for reduction in flood loss have to be considered. The natural retaining capacity of the catchment area can be increased, the level of investment can be modified, structural and emergency measures can be taken to diminish damage.

5. No flood protection measure can offer absolute certainty. Economic-statistical analysis can show which level of protection can give an optimal solution.

In case the sacrifices for protecting the entire region are too high, one can consider whether division of the flood plain in zones with different levels of investment will give a more economic solution.

6. Flood protection measures could interrupt the natural drainage, the natural colmation, and downstream channel process. Flood protection measures must therefore often be accompanied by drainage and irrigation, the improvement of old infertile levee, and channel training.

7. In cases where a country is very much dependent for its existence on flood control measures that take a considerable portion of the national product, special international aid must be considered.

IX. Recommendations on River Training

1. River training should in many cases not only be undertaken on behalf of flood control but also for inland navigation. The economy in transport cost and the difficulties in developing land-borne traffic make inland navigation an invaluable asset for many parts of the world.

2. Navigation also by larger units can already be made possible from the first development stage by an effective system of channel patrol. In non-tidal rivers local shoals can be eliminated by helping the river scour its own bed.

3. For bank protection, groynes and similar works, use has to be made of locally available materials. In many parts of the world traditional constructions exist and labour with special skill for making them is available. Modern materials science can help in finding means of stabilizing local soils. Where no wood is available, the water authorities can advantageously grow brushwood and reeds for their constructions.

X. Aspects of Organization of a Water Development Department; Training of Staff; International Co-operation

1. The ultimate shape on organization for water development will get and the system of engineering education will depend for each individual country on institutions preexisting in the country's own culture, outside historical influences and the national aims and ideals of the country.

2. A close co-operation will have to be established between all institutes collecting data or having another task for water development.

3. Co-ordination of the planning of water resources development must be laid in the hands of a strong national committee or organization. This organization will have to stay with its activities within the framework of the national economic and social plan.

4. Explaining the national water policies to the public is one of the tasks of the national water organization.

5. Local and regional interests must be given a voice in water development plans and the local authorities should, whenever possible, be given tasks in the implementation of the project.

6. Inland improvement schemes, extension services, co-operative associations and agricultural credit banks should be established well in time.

7. Engineering departments should have a big prestige through their integrity, knowledge and ability.

8. There is a close relation between a country's type of engineering training and the way of employment of engineers. Each country should find the system of training most suitable for it.

9. The under-graduate training of engineers and the training of personnel of sub-university level should take place in the country itself. If this is not possible, training will have to take place in the same climatic and cultural region.

10. For post-graduate training, regional seminars and courses will have to be held. Post-graduate courses on top level will be held only in a few places of the world

11. Use of foreign experts will have to be planned carefully. The expert must not only be good in his profession, but he should in the first line have a stable personality also under difficult circumstances. The expert should be prepared for the conditions he will find. The receiving country must clearly define the expert's task and provide him with a counterpart. In normal cases experts will not be given executive powers. The expert must have experience and knowledge of the work.

12. Co-operative systems of technical aid in the shape of mixed groups sent to the development country for training tasks and technical work and where the engineers from the development country

who have to take over later are trained in the aid giving country, can be most favourable in development aid.

13. Effective means of international help for water development are:

a) Giving assistance to UN organizations working in this field.

b) Undertaking projects of teaching and technical aid.

c) Doing research on behalf of water development under various climatic conditions.

d) Capital investment and loan aids.

e) Technical aid.

14. As the part of the national product of aidgiving countries that can be spent on development aid, is limited, compared to the big demands of water development in developing countries, criteria for the assessment of projects are necessary.

XI. Water Laws in Developing Countries

1. Major water projects loose much of their economic and social dynamism where by virtue of the existing laws the water resources cannot be marshalled in the public interest. No opportunity ought to be missed to impress on countries without modern water laws the urgent need for such legislation. Successful water development in a developing country should work towards the firm establishment of three institutions in its water code:

a) A politically strong department or statutory body which in the field of water affairs carries out the social and economic policy of government.

b) An advisory council on water affairs, nominated by the Minister.

c) Legal provisions adapted to the requirements of up-to-date water development practice and giving to the government ultimate control over all water resources. This may mean final departure from all traditional doctrines and the cancellation of all previous laws and ordinances by virtue of which it may have been previously possible to acquire water rights or licences or exercise direct control over bodies of water or discharge polluted effluents. An efficient administration of the water laws demands an accurate cadastre of all water resources and water uses. Priorities by law are a severe handicap for economic development.

2. There is no difference in principle between a water code for industrial countries and for developing countries of the tropical or subtropical zone, although a number of provisions may be different.

No detailed model water laws would serve any useful purpose; yet it is quite conceivable that for a region a general section of a water code could be developed into which the basic principles applying to all neighbouring countries could be incorporated, whereas every territory could add its own provisions.

3. In tropical and subtropical countries the absence of mutual agreements on international rivers must lead to loss of economic and social opportunity, and the help of the U. N. and its agencies for the negotiation of such international agreements is greatly welcomed. A first step towards the settling of disputes on international rivers is the setting up of common hydrological survey parties.

List of Participants

1. *Angerer*, Dr. H.
   Deutsche Landwirtschaftsgesellschaft e. V.
   Zimmerweg 16
   6 Frankfurt/Main, Germany

2. *Azam*, Khan Mohammad
   Chairman, Water and Power Development
   Authority of East Pakistan
   Dacca, East Pakistan

3. *Baity*, Professor H. G.
   Professor of Sanitary Engineering
   University of North Carolina, U. S. A.
   Formerly Director of the Division of Environmental Health, WHO
   6, Chemin Bizot
   Geneva, Switzerland

4. *Bassler*, Professor Dr.-Ing. Friedrich
   Institut für Wasserbau und Wasserwirtschaft
   Technische Hochschule Darmstadt
   Rundeturmstraße
   61 Darmstadt, Germany

5. *Bony de Lavergne*, M. de
   Société Grenobloise de l'Hydraulique-SOGREAH
   Ets. Neyrpic, B. P. 52
   Grenoble, France

6. *Ffolkes*, E. A.
   Chief Engineer
   Irrigation and Drainage Department
   Kingston, Jamaica

7. *Flathe*, Dr. H., Wissenschaftlicher Oberrat
   Bundesforschungsanstalt für Bodenforschung
   Wiesenstraße 1
   3 Hannover, Germany

8. *Friedrich*, Dr. W., Oberregierungsbaurat
   Bundesanstalt für Gewässerkunde
   Kaiser-Augustus-Anlagen 15
   54 Koblenz, Germany

9. *Giese*, Rudolf, Regierungsbaurat
   Bundesministerium für Ernährung,
   Landwirtschaft und Forsten
   Euskirchener Straße
   53 Bonn, Germany

10. *Gigas*, Professor Dr.-Ing. Erwin
Institut für angewandte Geodäsie
Forsthausstraße 151
6 Frankfurt/Main, Germany

11. *Hampe*, Dr. Rudolf, Ministerialrat a. D.
Am Stadtwald 36
532 Bad Godesberg, Germany

12. *Hartung*, Professor Dr.-Ing. Fritz
Lehrstuhl für Wasserbau und Wasserwirtschaft
Versuchsanstalt für Wasserbau der
Technischen Hochschule München
Arcisstraße 21
8 München 2, Germany

13. *Hartung*, Dr.-Ing. W.
Leichtweiß-Institut für Wasserbau und Grundbau
Technische Hochschule Braunschweig
Pockelstraße 4
33 Braunschweig, Germany

14. *Kleinsorge*, Dr. Hubert
Bundesanstalt für Bodenforschung
Wiesenstraße 1
3 Hannover, Germany

15. *Kuros*, Professor Dr.-Ing. Gholam Reza
Teheran, Iran

16. *Michael*, Dipl.-Ing. H. P., Reg.Dir.
Bundesministerium für Verkehr
sowie Technische Universität Berlin
Bertha-von-Suttner-Platz 2—4
53 Bonn, Germany

17. *Mostertman*, Professor ir. L. J.
International Course in Hydraulic Engineering
Delft Technical University
Delft, Netherlands

18. *Naylor*, Professor A. H.
Department of Civil Engineering
The Queen's University
Belfast, United Kingdom

19. *Niebuhr*, Dr.-Ing. Wulf, Ministerialrat
Abteilung Wasserstraßen
Bundesministerium für Verkehr
Bertha-von-Suttner-Platz 2—4
53 Bonn, Germany

20. *Özal*, Mr. Korkut
Ass. Professor
Civil Engineering Department
Middle East Technical University
Ankara, Turkey

21. *Preß*, Prof. Dr.-Ing. Heinrich
Institut für Wasserbau und Wasserwirtschaft
Technische Universität Berlin
Straße des 17. Juni, Ecke Bellstraße
1 Berlin 10, Germany

22. *Rao*, D. Sc. M. I. C. E. M. P., Dr. K. L.
Minister of Irrigation and Power
Government of India
New Delhi, India

23. *Roske*, Dr.-Ing. Kurt
Kreditanstalt für Wiederaufbau
Lindenstraße 27
6 Frankfurt/Main, Germany

24. *Ruhenstroth*, Wolfram ORLR
Bundesministerium für wirtschaftliche Zusammenarbeit
Kaiserstraße 185—201
53 Bonn, Germany

25. *Schönhals*, Professor Dr. E.
Bundesanstalt für Bodenforschung
Wiesenstraße 1
3 Hannover, Germany

26. *Stengel*, Mr. H. W.
Windhoek, South West Africa

27. *Tison*, Professor ir. L. J.
International Association of Scientific Hydrology
Gent, Belgium

28. *Vajda*, Andreas de
Chief, Special Fund Operations
Land and Water Development Division
FAO
Via delle Terme di Caracalla
Rome, Italy

29. *Volker*, Ir. A. C. E.
Directie Waterhuishouding en Waterbeweging, Rijkswaterstaat
Koningskade 25
s'Gravenhage, Netherlands

30. *Vollert*, Dipl.-Landw. Hans
Auswärtiges Amt
Wörthstraße
53 Bonn, Germany

31. *White*, Professor Gilbert F.
Department of Geography
Rosenwald Hall
University of Chicago
Chicago, U. S. A.

32. *Ulshoefer*, Dr. Otfried, Reg.-Ass.
Bundesministerium für wirtschaftliche Zusammenarbeit
Kaiserstraße 185—201
53 Bonn, Germany