WATER-RESOURCE ASSESSMENT ACTIVITIES

Handbook for National Evaluation

UNITED NATIONS EDUCATIONAL
SCIENTIFIC AND CULTURAL ORGANIZATION

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FOREWORD

No water-resource management or development, whether it be for the purpose of water supply for the population, agriculture, industry or energy production, is possible without an assessment of the quantity and quality of the water available. The United Nations Water Conference, meeting in 1977 in Mar del Plata, Argentina, recognized this fact and resolved that all efforts should be undertaken at the national level to increase substantially financial resources for activities related to water-resource assessment and that international co-operation aimed at the strengthening of water-resource assessment, particularly within the International Hydrological Programme of Unesco and the Operational Hydrology Programme of WMO, be keyed to the targets set by the Conference. In response to this resolution, WMO and Unesco initiated in 1979 an international project designed to assist countries to evaluate their current water-resource assessment activities and promote technical co-operation aimed at strengthening such activities where they are found to be insufficient.

Water-resource assessment is a national responsibility and any evaluation of the extent to which it is being undertaken adequately in a country is also the responsibility of the country concerned. However, internationally developed guidance on the subject can be of great assistance to the experts charged with undertaking such an evaluation. Use of this guidance can also lead to a certain degree of uniformity in approach between countries, something that can be very helpful in the development of regional and international co-operation with regard to water-resource assessment. Unesco and WMO therefore arranged for the development of a draft methodology for evaluating national water-resource assessment activities. This draft was tested in pilot projects by Australia, Federal Republic of Germany, Ghana, Malaysia, Panama, Romania and Sweden. It was also reviewed at regional meetings of experts in Africa (Harare, 1985), Asia (Manila, 1984) and Latin America (Montevideo, 1985). The methodology was then revised in the light of the experience thus gained and the many comments received.

The revised methodology is presented in this handbook for use by all charged with the task of evaluating the adequacy of water-resource assessment activities in any country.

The Secretariats of WMO and Unesco are interested to learn of the experiences of evaluators in the use of the methodology contained in this handbook and of any proposals for its further development and improvement.

1. INTRODUCTION

1.1 Background

Water resources can be neither developed nor managed rationally without an assessment of the quantity and quality of water available. This fact has been recognized by the United Nations Water Conference (Mar del Plata, 1977) in its Resolution I "Assessment of Water Resources" (see Appendix I). In this handbook, the definition of water-resource assessment is the determination of the sources, extent, dependability and quality of water resources on which is based an evaluation of the possibilities of their utilization and control.

In light of the above, the first step to be taken by any country in implementing the above resolution should be to carry out an evaluation of the country's present programme for water-resource assessment.

Two related activities should be executed concurrently:

(a) Evaluation of the present status and future needs of water-resource assessment throughout the country

(b) Development and strengthening of assessment programmes throughoug the country so that they adequately meet these needs.

1.2 Water-Resource Assessment (WRA)

Three stages can be identified in the implementation of programmes for the assessment of water resources:

- Basic water-resource assessment

- Extension of networks and more detailed investigations

- Management and control of water abstraction.

This handbook deals only with the first stage, i.e. the evaluation of basic WRA. Basic WRA involves the collection and processing of existing hydrological and hydrogeological data, plus the auxiliary data required for their areal interpolation, in order to permit a preliminary assessment to be made of available water resources on which to found national or regional long-term plans for overall water resources development, these plans being based on or keyed to present and future water needs.

1.3 Expected results of the evaluation

The results of the evaluation will be different for each country, depending on the characteristics of the corresponding basic WRA programme and the country's characteristics and needs. Nevertheless, there will be a minimum set of results that are expected to be obtained in practically each case. This set includes:

- an analysis of the existing institutional framework determining the basic WRA programme and the resulting advantages, disadvantages and related constraints;

- a comparative evaluation of the measurement networks and indications of network elements that require improvement with respect to station density, equipment, operational and supervision staff and other factors;

- a review of the available surveys and programmes for collection and processing of physiographic data pertinent to basic WRA and the corresponding needs related to areal extension of basic WRA;

- an evaluation of the application of various techniques for areal extension of basic WRA and related data and information transfer techniques used in the country and of the related uncertainties and future requirements;

- an analysis of the hydrological information requirements for long-term planning, of the production and flow of this information to the user, and of the results of the use of such information in the planning process which demonstrates the basic WRA programme adequacy or inadequacy;

- an estimation of manpower and skills required for an adequate basic WRA programme and appraisal of existing education and training programmes when compared to current and future requirements;

- a review of basic and applied research activities in the country (and region), their adequacies (or inadequacies) for water-resource assessment when compared to current and future needs including needs for scientific and technological regional and international co-operation;

- indications as to the major sources of inadequacies in the programme in terms of institutional framework, financial resources, instrumentation, techniques and others;

- recommendations for eliminating the inadequacies of the basic WRA through means of national or regional co-operation and/or international aid.

1.4 Purpose of handbook

The purpose of the methodology proposed in this handbook is to indicate practical methods of evaluating current levels of the basic WRA programme in the whole or part of a country. The current levels are compared with minimum acceptable requirements in terms of installations, equipment, skilled manpower and related superstructures and education, training and research. This comparison provides a basis for proposing the action considered necessary to achieve the minimum requirements. The methodology will also provide a practical basis for planning international assistance to countries with inadequate basic WRA programmes.

It was not considered advisable to attempt developing a uniform methodology for evaluation of WRA programmes in all countries because of the large variations which exist from one country to another from the viewpoint of basic WRA and political, socio-economic and technical circumstances. Hence, it should be pointed out that the methodology is to be regarded only as a guideline for use in national evaluation.

1.5 Scope of handbook

The scope of this document is limited to a proposal of a methodology of evaluation of basic WRA programmes. This limitation was adopted as the second and third stages of WRA are related to the analysis of water supply and demand and its evaluation requires comprehensive consideration of economic and social factors, which is beyond the scope of the international project initiated by WMO and Unesco.

On the other hand, basic WRA depends mainly on natural conditions, therefore reference levels and other adequacy guidance can be developed on a regional basis. These reference levels or criteria may be established for use in determining the extent to which a basic WRA programme is satisfactory.

One major purpose of the methodology developed in this handbook is to provide a practical basis for planning international assistance for upgrading basic WRA programmes when they are less than adequate. Consequently, the document is focused on the developing or least developed countries although for methodological reasons, the case of countries with adequate programmes is also considered. This is required because data from countries with adequate WRA programmes may be used to obtain valuable indications on relevant reference levels and techniques.

Because this handbook aims to present a practical methodology, its scope includes some general guidance and criteria that are easy to obtain and apply in practice, as will be shown in Section 1.7.

Application of the methodology yields an objective evaluation, but the conclusions and recommendations based on it should take into account many socio-economic, administrative and other factors which cannot be included in the methodology itself.

1.6 Approach

The handbook presents a step by step evaluation approach. This does not imply a rigid methodology of evaluation as conditions determining WRA programmes are extremely varied from one country to another. Significant adjustments will have to be made to the proposed methodology to adapt it to this variation.

However, for the basic WRA, that is for the inventory of water availability, the assessment requirements can be expected to show limited variation for similar natural conditions. Therefore the experience obtained in one country or region is to some extent transferable to a country or region with similar hydrological conditions. Consequently the approach suggested is based on activity and reference levels relating to conditions observed in countries with various hydrological characteristics, in which the basic WRA is generally considered to be adequate.

The approach is aimed at enabling the evaluator to examine the various components of a WRA programme and identify in each case, on the basis of the reference levels, the basic causes of inadequacies. The latter may originate in legislative-administrative constraints, or lack of funds, equipment or personnel, or a combination of these. In each particular case the evaluator will be required to use considerable judgment in identifying the above-mentioned cause or causes. However, the results of the evaluation carried out as indicated in this document should provide him both with the required information on the state of the WRA programme of a given country and with a basis for substantiating his conclusions and recommendations as to remedial action, including international aid.

1.7 Evaluation elements and levels

The evaluation will be based on a series of levels characterizing the various activities and elements required for obtaining the components of a basic WRA programme together with its supporting activities.

1.7.1 Activity levels

Activity levels are absolute or relative numerical characteristics of the WRA programme components reflecting the current status of development of the different related water-resource elements for the area under consideration. They can be used to compare different programmes and possibly to indicate reasons for inadequate performance. The adequacy of activity levels will be established by the evaluator using comparisons with similar levels obtained in countries with adequate WRA programmes and with his own judgment, experience and knowledge of the country's conditions. When certain activity levels prove to be adequate in a number of cases they may be accepted as reference levels.

1.7.2 Reference levels

For the purpose of the evaluation, reference levels are defined as absolute or relative numerical values indicating the minimum requirements of evaluation elements with which a basic WRA programme in a country or region should comply to be considered adequate.

Certain reference levels may be based on values or ranges of values accepted by the relevant international organizations. These are related primarily to natural hydrological conditions. Such reference levels are expected to be valid in all countries (regions or countries) with similar natural conditions.

Preliminary reference levels for basic WRA are suggested in Appendices IV to VII and are based partly on WMO recommendations (WMO, 1981). The numerical values corresponding to those levels are underlined in the following examples:

Region: Tropical, arid and sedimentary
Density of non-recording precipitation stations:
6 stations per 10 000 sq km

Region: Temperate, arid and sedimentary
Number of water quality stations served by each water quality lab:
20 stations per lab.

In deriving activity and reference levels, it is necessary to use a dynamic approach, in the sense that past and future conditions should be considered when relevant. For example network stations that have been operated for a long time and are currently closed because incremental data would not significantly increase the information already collected should be considered in counting the number of stations. On the other hand, existing network superstructures that are scheduled to disappear in the near future following the end of an external aid programme should be considered only in a qualified manner. Deficiencies that will certainly be corrected in the near future should also be thus qualified and the corresponding levels considered accordingly. It is also necessary to make adjustments according to the major climatological and geological characteristics of the country (or region).

1.7.3 Emphasis level

For the various activities considered, which are referred to as evaluation elements, the approach proposes the use of variable levels of emphasis in the evaluation according to the particular conditions of the country or region being evaluated. A low emphasis indicates that the activity (evaluation element) can be ignored in the evaluation if data are not readily obtainable. A medium emphasis indicates that the level should always be considered when data on it are available, and that some efforts should be made to obtain them. A high emphasis indicates that information on the activities is absolutely necessary for the evaluation. For instance, in the example presented in 1.7.2, the reference level for tropical, arid and sedimentary regions is 6 stations per 10 000 sq km and it is proposed that the emphasis for precipitation stations (Appendix IV) in such regions be "HIGH", meaning that a knowledge of the activity level for this element is absolutely necessary.

1.7.4 Regionalization

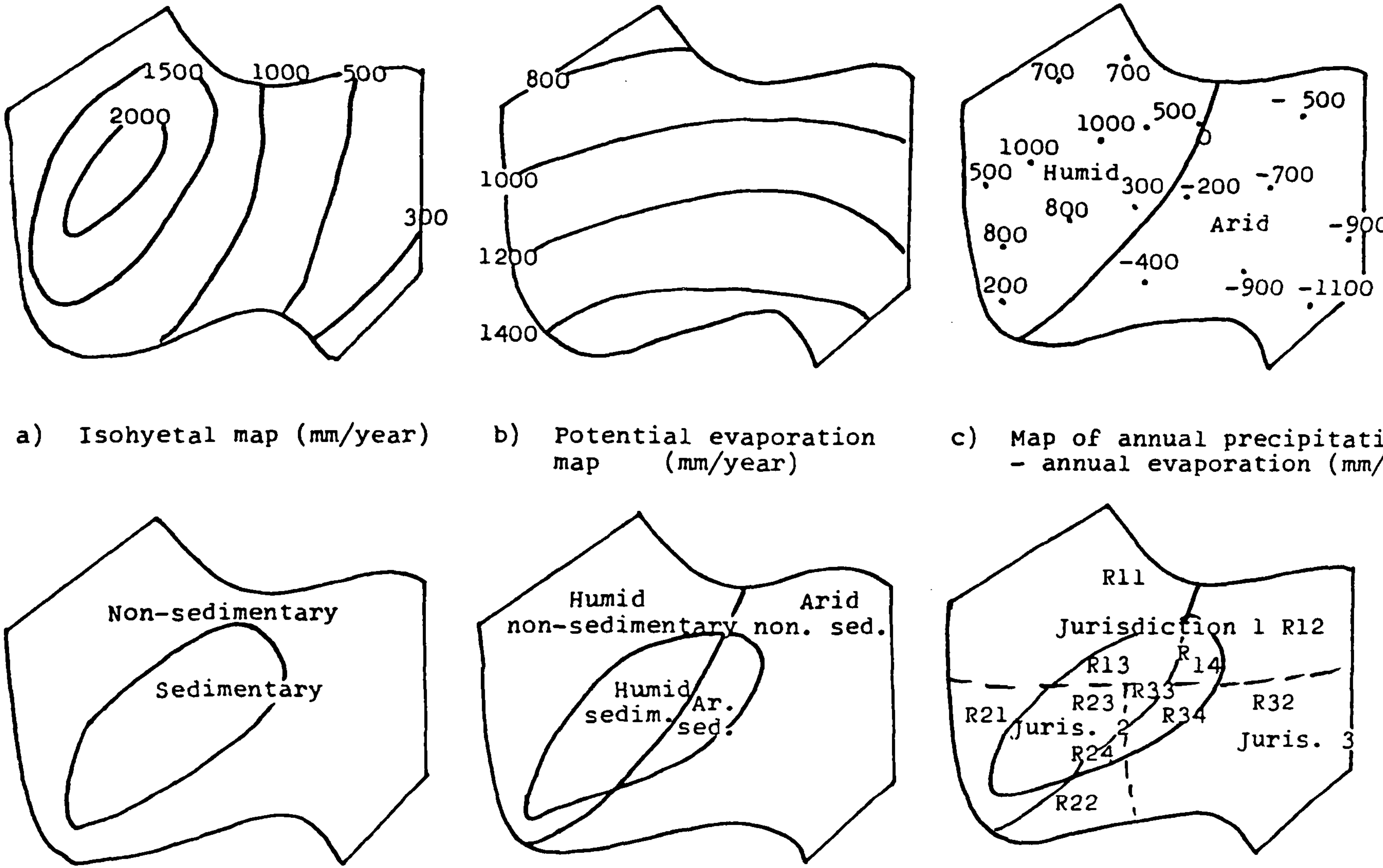
As mentioned above, the levels of activity, reference levels and emphasis which are to be established for the purpose of the evaluation will vary with the particular natural and socio-economic conditions of the country evaluated. Not all the relevant conditions in countries can be readily foreseen. However, as a starting point, and to maintain this document within practical limits, it is proposed that the variations in activity and reference levels and emphasis levels be presented in terms of major climatic and geological characteristics of the country.

From a climatic viewpoint the variation considered is between humid and arid. For the purpose of this handbook, an arid climate is defined as a climate in which mean annual precipitation is less than the mean annual potential evaporation. Conversely, in a humid country, the latter is less than mean annual precipitation. Natural hydrological characteristics are obviously different in arid and humid countries. In addition, organizational, technical and economic water use problems are also basically different in humid and arid countries or regions. In humid countries water availability is usually an auxiliary element in most economic activities, other resources being the main development factor. In arid countries water availability is frequently a prime development factor. Therefore, activity and reference levels and the emphasis on their use in evaluation of WRA programmes will be different in arid and humid countries or regions.

Basic water-resource characteristics may also vary significantly from one country or region to another in terms of the surface geology characteristics. In countries or regions with significant superficial sedimentary deposits one may usually expect significant groundwater resources in addition to the surface resources, whereas in countries without such deposits the importance of groundwater is frequently less. The values and emphasis of the various activity and reference levels for evaluating basic WRA vary therefore with the major surface geology conditions (sedimentary or non-sedimentary) of the country.

Sharp variations of climatic and/or geological characteristics within a country may lead to the necessity of subdividing the country into subareas for which the appropriate activity and reference levels can be applied. On the other hand, the proposed climatic and/or geological characteristics may offer almost no subdivisions in other countries.

The use of activity and reference levels in the evaluation is based on a variation in emphasis allocated to the above in accordance with the climatic-geologic characteristics of the area. Accordingly, the evaluator should regionalize the country in accordance with the major climatic (arid/humid) and geologic (sedimentary, non-sedimentary) characteristics. For this purpose the evaluator should obtain a map of mean annual isohyets and a map of potential evaporation, both expressed in mm (maps a and b in Figure 1.1). By overlaying the two maps and subtracting from the precipitation values of map a the potential evaporation value of map b, the evaluator will obtain a map showing positive and negative values (map c in Figure 1.1). Areas with positive values will be zoned as humid, the others as arid. By overlaying on this map a geological map on which areas with sedimentary and non-sedimentary surface formations have been separated (map d), the evaluator will obtain a map such as that shown as map e, on which it is possible to delineate the four climate-geologic regions used in the handbook humid non-sedimentary, humid sedimentary, arid non-sedimentary and arid sedimentary. By overlaying on map e the map of the geographical boundaries of WRA jurisdictions, the evaluator will be able to delineate the geographical boundaries of the four regions in each jurisdiction. Of course, in many jurisdictions the number of regions will be less than four and a large number of jurisdictions may be related to one single region.



a) Isohyetal map (mm/year)

b) Potential evaporation map (mm/year)

c) Map of annual precipitation - annual evaporation (mm/year)

d) Geological regions

e) Climatic-geological regions

f) Jurisdictional climatic-geological regions

Figure 1.1 - STEPS IN REGIONALIZATION

The scale of the maps to be used may vary with the size of the country. For countries between 100 000 and 250 000 sq km, 1:250 000 to 1:500 000 maps are adequate. For countries between 250 000 and 2,500 000 sq km, 1:1 000 000 or 1:2 000 000 maps would be acceptable. For countries larger than 2 500 000 sq km maps 1:5 000 000 could be used.

Where detailed maps are not available, the evaluator could use general maps such as those included in the Atlas of World Water Balance (Unesco, 1978), as the accuracy of the delineation of the climate-geologic regions will not have a very significant effect on the evaluation process.

If sharp variations exist in the level of the basic WRA in various regions or subregions of one and the same country, each region or subregion of the country should be assessed separately. This is required for two major reasons: to avoid the use of unrepresentative values; and to obtain data on successful basic WRA programmes in subregions of countries which on the whole, may have inadequate basic WRA.

1.8 Economic considerations

The economic aspects of basic WRA are outside the scope of this document. Although basic WRA is costly, the experience of several countries indicates that where a benefit/cost ratio can be estimated, this ratio is generally much higher than one (Reynolds, 1979). However, this should not be construed to indicate that basic WRA cannot be wasteful under certain circumstances. In order to avoid this, it is necessary to keep in mind that the standard error of estimate of various characteristics of a water resource initially decreases very rapidly with the increase of the density of stations or length of the period of record, and that this decrease becomes much slower as the density or the period of record increases more and more.

In addition to this consideration, obtaining high benefit/cost ratios requires that the data obtained are relevant. Basic WRA data are relevant when they can be used at least for inventorying the resource and general long-term planning. Even establishing the absence or insufficiency of resources in certain areas can be useful.

Various techniques for planning basic WRA data networks are discussed in WMO (1972) and WMO (1976). A detailed discussion on the evaluation of costs and benefits of hydrological services is presented in WMO (1977). An analysis of the returns obtainable from meteorological data, which goes far beyond the field of water resources can be found in Maunder (1970).

1.9 Structure of the handbook

The evaluation will be focused on the basic WRA programme, i.e. on the inventory of water available for various uses, including characterisation of time-space variation of water quantity and quality. This type of inventory is required at any point of the area covered, and may be considered to consist of three components (Figure 1.2):

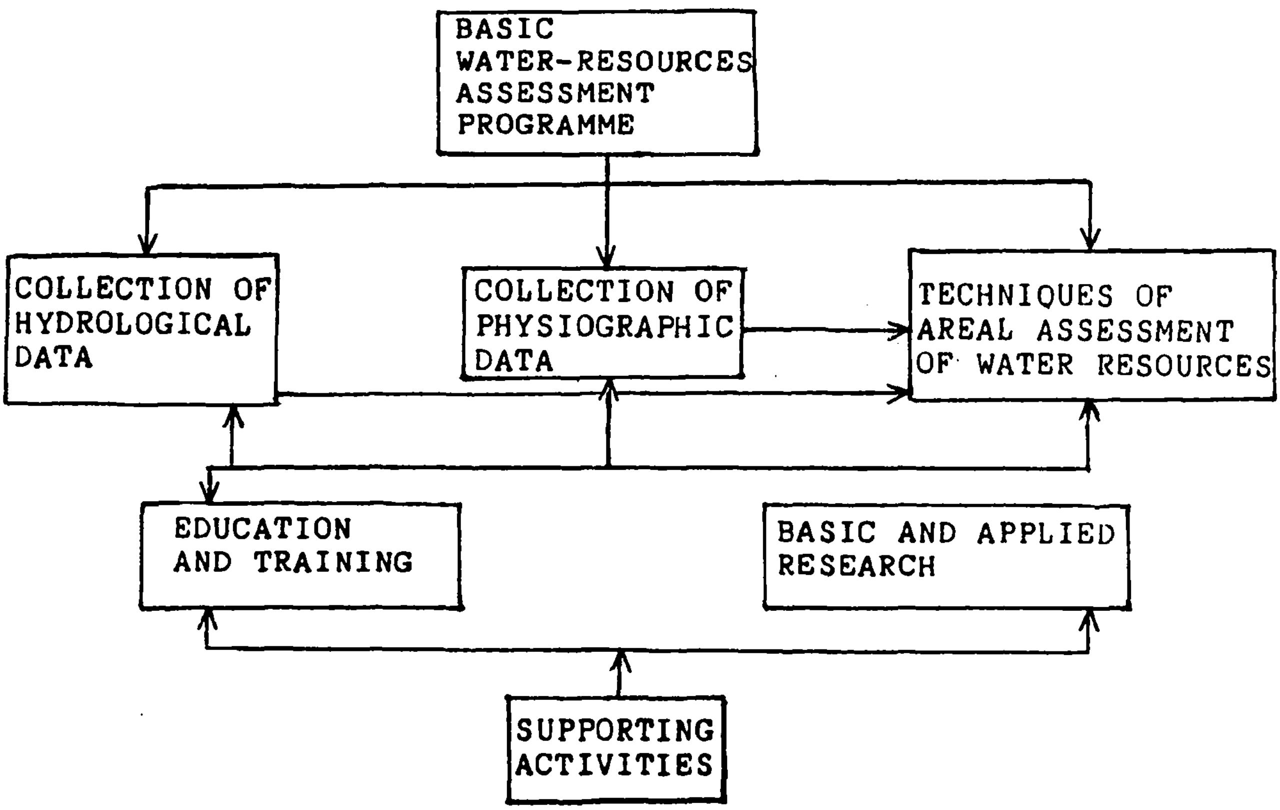


Figure 1.2

COMPONENTS OF A BASIC WATER-RESOURCE ASSESSMENT PROGRAMME

(a) Collection of hydrological data - the collection of historical data on water cycle components at a number of points distributed over the assessment area.

(b) Collection of physiographic data - obtaining data on the natural characteristics of the terrain that determine the areal and time variations of the water cycle components, such as topography, soils, surface and bed rock geology, land-use and land-cover. These characteristics are designated for brevity as physiographic characteristics.

(c) Techniques of areal assessment of water resources - techniques of transforming data into information and of relating the hydrological data to the physiographic data for the purpose of obtaining information on the water-resource characteristics at any point of the assessment area.

Evaluation of water cycle and physiographic data collection activities are discussed in Chapter 3.

The basic WRA programme is considered adequate if the three components of the programme are available and, by relating them, sufficiently accurate to supply water-resource information required for planning purposes at any point of the assessment area (Chapter 4).

This will require definition for the given country of the type of information required for planning, the manner in which this information is produced and transmitted to users and the effects of lack of information or inaccurate information on the decision-making process at the planning stage (Chapter 5).

All basic WRA activities require skilled manpower and efficient equipment and techniques for field surveys and network design and operation and development of reliable areal interpolation techniques. This in turn requires training and education of the required manpower, and basic and applied research for developing the required technology. The approach suggests that an analysis of these activities can provide indications of their adequacy for the purpose of basic WRA or, when they are inadequate, on the required additional means to be devoted to them to provide the required base for future development of an adequate WRA programme (Chapters 6 and 7).

Guidelines for the evaluation of all mentioned WRA related activities are included in Chapter 8 of this handbook.

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2. INSTITUTIONAL FRAMEWORK

2.1 Introduction

Basic WRA is not something that is undertaken only once. It is a continuous activity providing increasingly accurate information on the availability of water resources in the investigation area. Water-resource characteristics vary continuously in time and space. Therefore, the accuracy of information on water resources provided by a basic WRA programme depends on the equipment and frequency of measurement, the length of the record, the density of measurement points and the method of interpolation and type and accuracy of physiographic data used in interpolation. In addition, changing socio-economic and environmental conditions and modification in the range and development targets set in an area exert changing requirements on the accuracy of basic WRA data required. If a basic WRA programme is to be valid even where rapid changes are made in development plans, it has to cater for any conceivable development alternative and be fairly independent of any concrete short-term or medium-term water-resource planning and development projects. For this to be possible it is necessary that a certain institutional framework exists ensuring the continuous basic WRA activities.

The institutional framework of basic WRA consists of:

(a) collection of water-resource data and those which need such data and which process them into corresponding information;

(b) collection and processing auxiliary (physiographic) data required for the interpolation of water-resource information;

(c) training and education of the personnel required;

(d) basic and applied research related to WRA.

2.2 General administrative-legal framework in relation to water-resource planning (WRP)

The basic administrative-legal framework of WRA is a component of a wider institutional system which ensures the inventory, development, planning and management of the natural resources of the given jurisdiction. A starting point for establishing the major components of this framework can be found in the information provided by WMO (1977a and 1977b) and Unesco (1969).

2.2.1 Definition of general administrative-legal framework

The totality of institutions involved in long-term WRP and basic WRA and the legislation and regulations (written or oral) governing the activities of these institutions constitutes the general administrative-legal framework of the WRA programme. This framework varies widely from one country to another.

2.2.2 Description of general administrative-legal framework

Defining the general administrative-legal framework of WRA in its relationship to long-term WRP requires an understanding of the relationship that exists between long-term WRP and WRA, and knowledge of the legislation that governs these activities. The former has a more general character; the latter is specific to each country. A further complication results from the areal boundaries of jurisdiction of various institutions.

2.2.2.1 Long-term WRP and relationships to basic WRA

Long-term water-resource planning involves the forecasting of water demand and corresponding development of water resources from potential into actual resources, in accordance with the economic and other long-term objectives of the social groups having jurisdiction, ownership or other rights over the potential water resources under consideration.

When using the term "water resources" recognition is given to the fact that the simple existence of a source of water does not automatically define it as a water resource. For water to be a resource it must be available, or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand. There are many such demands, each with its own requirements, and account must be taken of the socio-economic as well as the physical circumstances surrounding each potential demand-resource interaction.

The water supply-demand interaction embraces many forms according to the type of use. It should be borne in mind that in all cases this interaction includes water quantity and quality aspects.

From the viewpoint of WRA water uses can be divided into three major groups:

(a) Those in which the prime development element is the availability of water itself in certain favourable circumstances. Such is the case with hydroelectric power and fisheries. In some circumstances drinking water supply, water for waste disposal, irrigation and recreation could be included.

(b) Cases in which water plays a secondary, auxiliary role and development takes place because of a number of favourable conditions of which water is not the most important one. These are for example, primary extractive industries, oil, processing and construction materials industries and water transportation (including hydraulic transportation of minerals). Sometimes, such uses as drinking water, irrigation, recreation, fish farming, livestock watering will have to be included.

(c) The third group is related to the deleterious effects of water which could be labelled as "negative uses". One could include in this group the effects of water quantity (flooding of residential or industrial areas and farmland, excess water in mines), effects of erosion and sedimentation, and effects of naturally poor or deteriorated water quality (direct or vectorial spreading of diseases, increased cost of water treatment, reduction of value of riparian real estate and of recreational value, etc.).

To be complete, a basic WRA programme should include institutions which have the task of supplying all the relevant water-resource inventory information. In addition, the usefulness and continuity of the basic WRA programme depends also upon the existence of the institutions involved in long-term WRP that require and use this information, thus continuously checking and correcting (improving) its efficiency.

2.2.2.2 Areal framework

An essential starting point in defining the general political-administrative WRA framework is the definition of the areal framework (boundaries) within which the assessment is taking place. Three types of areas have to be considered in establishing such a framework.

The first is the natural river basin or aquifer boundaries, that is, the boundaries of the area which is drained by the river or underlaid by the aquifer under consideration. The second is the jurisdictional region. This is the region over which the same government or water-resource owner has authority the basic use of the water resources. Usually, water diversion from one basin to another is legally possible within such a region. The third is the economic region: the region within which the movement of people and merchandise is unimpeded by fiscal barriers, and within which alternative locations of industrial and other development can be selected without extraneous differential incentives (disincentives). The river basin or aquifer framework makes it easier to assess the potential water resources of the area. The jurisdictional and economic regions make it easier to plan water-resource development and consider water-resource diversions.

When the boundaries of the three types of regions coincide, the areal framework for WRA in its relation to WRP is obviously the common area of the three regions. However, in practice this is rarely the case. Frequently, the boundaries of two of the areal elements coincide (particularly the jurisdictional and economic regions). In such cases it is also easy to select the assessment areal framework for water supply-demand as the one which is common to at least two of the three types of regions, but this requires the introduction of boundary conditions in the assessment to take into account the effects of the non-coincidence of one of the regions to be considered with the assessment area. When a river basin is divided into several jurisdictional regions, the WRA for the whole river basin requires a co-ordination between the jurisdictions. In such a case, the inflow-outflow characteristics of the jurisdictional boundaries may have been already defined in existing agreements between the jurisdictions, or may have to be agreed upon on the basis of the findings of the assessment. When all three sets of boundaries are different, the problem becomes quite complex as, independently of the areal framework selected, a large number of various types of boundary conditions has to be considered. In such cases, jurisdictional arrangements making it possible to include a whole river basin in the assessment area are probably advisable and examples of such arrangements are available in many areas of the world (UN, 1977, WMO, 1977a).

2.2.2.3 Legal factors

The general political-administrative framework of a WRA programme depends, sometimes significantly, upon the legislation governing various aspects related to basic WRA, namely legislation:

- establishing the responsibilities and rights of the organization(s) entrusted with long-term WRP and basic WRA;

- establishing standards and norms to follow in carrying out WRA, particularly basic WRA;

- enabling WRA activities to be carried out on private land or waterbodies.

The word "legislation" should be interpreted in a broad sense as the totality of relevant juridical regulations, which is also related to jurisdiction levels according to the country organization.

Legislation in this field varies enormously from one country to another and has a significant bearing on WRA activities. In some countries such legislation may be completely lacking and activity is based on unwritten but generally accepted (traditional) rules. In other countries, lack of legislation and related institutions may be at the source of inadequate (or even non-existent) basic WRA programmes.

2.2.3 Analysis of general administrative-legal framework

An understanding of the general administrative-legal framework of WRA in relation to long-term WRP is required for the evaluation of the basic WRA programme.

For this purpose the evaluator should:

- identify the institutions that require basic WRA information for long-term water-resource planning purposes (WRP);

- identify the institutions that collect basic WRA data and process them to provide the required information;

- establish the areal jurisdiction of the various institutions involved in long-term WRP and basic WRA and the resulting needs for providing boundary conditions;

- identify legislation governing the activities of long-term WRP and basic WRA (or generally corresponding to accepted traditional rules);

- analyse relationships between various institutions and the corresponding jurisdictions and - where applicable - identify lack of proper institutions and/or legislation.

2.3 National and local institutions performing basic WRA

In most countries a number of institutions at the national or local level perform various activities that could be included in the basic WRA. In addition to identifying them, it is necessary to define the space and time dimensions of these activities to obtain a comprehensive description of the WRA work carried out in the country in preparation of its evaluation from the viewpoint of coverage and accuracy.

2.3.1 Definition of tasks

National or local institutions to be considered as part of the basic WRA programme are institutions whose water cycle related activities include one or several of the following tasks:

- planning, designing, installing, operating of systems of collection of water cycle data (i.e. precipitation, runoff, air and soil moisture, evaporation, groundwater) and making the data available to users;

- processing of water cycle data with the purpose of obtaining information on the statistical or deterministic characteristics of the water cycle characteristics (e.g. yearly or seasonal means, standard deviations, time series statistics, mean annual runoff maps, precipitation or runoff corresponding to given storms, flood flows of a given return period).

2.3.2 Description of institutions

The institutions involved in basic WRA to be considered are all institutions carrying out the tasks discussed above for one or several components of the water cycle. In some cases, both sets of tasks are carried out by one and the same institution for a given water cycle component. In other cases the two sets of tasks are carried out by different institutions.

For the purpose of simplifying the discussion of the different types of basic WRA institutional set-ups that might be encountered in practice, these are grouped into three main types:

(a) Vertical. The limits of the jurisdiction coincide with those of one or several watersheds and, within those limits, basic WRA tasks are carried out by one and the same institution.

(b) Horizontal. Basic WRA activities are split among several institutions in a similar jurisdiction. For example, separate organizations are involved in collecting data on various components of the water cycle such as precipitation, river flow and groundwater, whereas other institutions are involved in developing information such as the areal distribution of these components.

(c) Complex. The watershed is divided into several jurisdictions and there are one or more basic WRA institutions within each jurisdiction.

Vertical, horizontal and complex institutional set-ups can be found at various administrative levels (inside a province, state, or prefecture, at the level of a country, or at the international level). Each type of institutional arrangement is the result of a long historical evolution and changing from one type to another is generally difficult. Unesco (1969), UN (1974, 1975) and WMO (1977) provide descriptions of the various actual institutional arrangements found in various countries. As can be seen from these publications, the most frequent types of institutional arrangements are the horizontal and complex ones. It should be noted that in some cases the arrangements may appear as horizontal when in fact they are complex. This is because the reporting on the existing institutions was done by one level of government only.

2.3.3 Analysis of institutional arrangements

The large variation from one country to another of the institutional framework within which basic WRA may take place makes it necessary to adjust the evaluation of the basic WRA programme of a country to the specific conditions of that country. For this purpose, it is necessary first to carry out a survey of the institutions that participate in this assessment and their co-ordination. Such a survey is necessary for two major purposes: to exhaustively inventory and evaluate the basic WRA activities; and to evaluate the influence of the institutional framework on the complexity of the basic WRA programme.

The first step required in evaluating the institutional framework is to establish the type of organization (vertical, horizontal, complex).

The second step consists of identifying the institutions involved: in the case of a vertical organization one institution; in the case of a horizontal organization a number of institutions involved in various components of the hydrological cycle and various tasks; in the case of complex organizations the same as above for each jurisdiction. The result of this step could be presented in the form of one or a series of organization charts or tables. A starting point can be found in WMO (1977), UN (1974 and 1975) and Unesco (1969).

The third step consists of identifying, for each institution, its tasks for data collection and information production separately for each jurisdiction and defining the space-time limits for each task. The results may be presented in Table 2.1.

The fourth step consists in determining with aid from the above table the:

(a) boundary interfacing conditions requirements;

(b) activity duplication;

(c) inefficient utilization of measurement and inspection crews;

(d) inconsistencies in standards and techniques;

(e) insufficient data and information exchange.

In this step the streamlining of the WRA programmes that may be obtained through interjurisdiction co-ordination and co-operation and interjurisdiction compacts or boards should be considered.

2.4 International co-operation

One major purpose of this document as stated in Section 1.4 is to provide a practical basis for planning international assistance to countries with inadequate water-resource programmes. In view of this, it is important to recognize the significance of international programmes and co-operation in assisting various countries with their water-resource activities.

Appendix II examines the contribution of international organizations and agreements to basic WRA. A more detailed discussion of this subject can be found in Nemec (1976) and in UN (1977).

2.4.1 Needs for and benefits from international co-operation

International co-operation in basic WRA is needed for a number of purposes, and mainly for:

- basic WRA at continental and global scale;
- development and implementation of advanced techniques of collection and processing of data in the water cycle components and of providing information on the same;
- technology transfer in the field of basic WRA;
- organization of co-operative efforts in carrying out basic WRA in international basins;
- providing data at boundaries of countries when WRA is carried out separately by various jurisdictions;
- organizing and implementing international aid in the field of basic WRA;
- exchange technical and methodological information on basic WRA.

2.4.2 Significance of international co-operation programmes for basic WRA

Involvement of a country in international co-operation programmes related to water resources may be of significance both in evaluating the existing programmes and in setting up plans for upgrading the existing programmes to satisfactory levels. As the focus of this project tends towards developing countries, this significance is outlined for these types of countries only.

Completion of Table 2.2 will illustrate the extent to which the country participates in the hydrological activities of the programmes of the main international organizations having programmes related to WRA. The most important of these organizations are referred to in Appendix II.

The information presented in Table 2.2 can give only a very general and indirect indication of the extent to which basic WRA activities in a country benefits from international programmes, in particular technical co-operation and assistance. In some countries a major part of the basic WRA programme has been developed or is supported with external sources of finance and an evaluation of the WRA programmes in such countries would not be complete without some recognition of this fact.

References to Chapter 2

Nemec, J. (1976) - International Aspects of Hydrology. In Facets of Hydrology, Edited by J.C. Rodda, John Wiley and Sons, London.

UN (1974) - National System of Water Administration, Dept. of Economic and Social Affairs, New York.

UN (1975) - Management of International Water Resources: Institutional and Legal Aspects, Natural Resources, Water Series No. 1, New York.

UN (1977) - Present and Future Activities of the United Nations System in Water-Resources Development, UN Water Conference, Mar del Plata, Argentina, E/CONF. 70/CBP/4. Pergamon Press Ltd., Oxford.

Unesco (1969) - Water Services in the World, Document SC/W5/249, Paris.

WMO (1977a) - Statistical Information on Activities in Operational Hydrology, Operational Hydrology Report No. 10, Geneva.

WMO (1977b) - Casebook of Examples of Organization and Operation of Hydrological Services, Operational Hydrology Report No. 9, WMO - No. 461, Geneva.

TABLE 2.1 - INSTITUTIONS AND TASKS INVOLVED IN BASIC WRA

Main type of activity \ Jurisdiction												
	Institution	Tasks	Area covered	Task starting date	Institution	Tasks	Area covered	Task starting date	Institution	Tasks	Area covered	Task starting date
Meteorological												
Hydrological												
Hydrogeological												

Note: Appendix III presents an example of the use of this table.

TABLE 2.2 - PARTICIPATION IN INTERNATIONAL WRA PROGRAMMES

International organization and/or programme	Corresponding national institution	Level of* participation

* Indicate low, medium or high.

3. DATA COLLECTION, PROCESSING AND RETRIEVAL

3.1 Introduction

The main activities required for basic assessment of water resources are data collection, processing and dissemination. Three types of data are usually required: data on the water cycle, data on water use projects, auxiliary data which are used for interpolating network data to any point of the area under consideration. These activities are crucial for the basic assessment of water resources and their adequacy is of foremost significance in evaluating the WRA programme of a country.

This chapter is concerned mainly with data. However, reference is made occasionally in this chapter and in subsequent chapters to information. For the purpose of the evaluation, data are defined as numerical expressions of measurements of some dimension of a natural or man-made object or phenomenon. Information is defined as the result of processing time and space series of data in various ways so as to provide insight into the characteristics of the object or phenomenon, and for use in decision making.

3.2 Data on the water cycle

3.2.1 Data needs

Basic WRA requires data on the variation in time and space of the flows and physical, chemical and biological characteristics of water present in the various elements of the water cycle (precipitation, evaporation, air humidity, runoff, river, lakes, snow and ice, soil moisture[1], groundwater). Data needs may have different priorities in different countries, or even in different regions of one and the same country. These priorities are determined on one hand by the current and future needs of the users and, on the other, by the characteristics of the available water resources. However, the latter cannot be estimated without information obtained from basic WRA.

3.2.2. Water cycle data systems

Techniques for collection of data on the water cycle are described in detail in WMO (1981) for surface water and Unesco (1977) for groundwater.

Data on the water cycle are collected mostly through conventional measurement networks. More recently, collection of some of these data through remote sensing (air surveys and satellites[2] (WMO, 1979) has become significant and the use of such measurements is increasing rapidly.

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[1] Soil moisture is in many cases estimated indirectly using water balance and other techniques. Therefore this element is not considered explicitly in this chapter.

[2] Most countries cannot afford their own data collection satellites but can benefit from satellites launched by others.

Collection of water cycle data requires an infrastructure (stations, data transmission and measurement equipment, repair and maintenance shops, rating laboratories, airplanes, satellite receiving stations and corresponding staff of observers, technicians and engineers) and a superstructure for planning the data collection system, and its operation, and for checking and primary processing of the data. The infrastructure is an element which can be readily characterized quantitatively and qualitatively. The superstructure is usually more difficult to characterize, particularly from the quality viewpoint.

3.2.2.1 Infrastructure

Data collected in the time and space variation of water cycle elements can be separated into three major groups: historical data, real-time data, and special survey data. Historical data are data collected to obtain the space-time series of data on water cycle elements for long-term characterization of these elements. Real-time data are data transmitted as recorded to data collection, processing and dissemination centres, for monitoring and forecasting of water-related phenomena for various practical operational purposes. Of course, real-time data can be used also, after accumulation, as historical data. The infrastructure of the two systems are different, that for the historical data being much simpler than that for the real-time data. The special surveys data are data collected instantaneously or for short duration in certain areas, in connection with studies of rare events or special purpose studies or for initial exploratory purposes preceding, for example, installation of permanent stations, or for data interpolation purposes.

3.2.2.1.1 Historical data

The infrastructure for obtaining historical data consists usually of:

- measurement (gauging) sites;
- measurement equipment (fixed such as rain gauges, river gauges, and portable such as current meters, well drilling equipment);
- operating staff (site bound such as observers and itinerant such as flow measurement teams, well drilling teams);
- equipment rating and testing installations and staff;
- maintenance and repair shops and staff;
- equipment manufacturing shops and staff (not absolutely required when equipment imported);
- water quality, hydrobiological and sediment analyses laboratories and staff.

The historical data infrastructure is the essential component of basic WRA. Although it is conceivable to use remote sensing techniques for collection of historical data, these techniques are used mostly for collection of real time and special survey data, and are discussed under those headings.

3.2.2.1.2 Real-time data

Real-time data collection is not essential for basic WRA. However, it does contribute in several ways to this assessment by: increasing the density and frequency of data; providing, particularly through meteorological and environmental satellites, basic information for areal interpolation of point data as indicated in Chapter 4; and by providing valuable information for the operation of the network such as warning on malfunctions, exceptional high or low flow for which teams should be dispatched for flow measurements, accessibility of gauging stations, etc. Such data are recorded and transmitted to data collection centres either instantaneously or with short delays.

3.2.2.1.3 Field surveys

Field surveys are defined for the purpose of the evaluation as surveys of water cycle and physiographic data that are carried out occasionally or routinely in addition to network-based surveys. Examples of routine field surveys are snow surveys. Examples of occasional field surveys are reconnaissance trips for finding groundwater resources and special flow measurement programmes in an area during a drought. Field surveys can be carried out using surface or airborne equipment. The use of remote sensing and nuclear techniques for field survey of snow and soil moisture has recently become the object of particular attention (WMO, 1979). For field surveys, possibilities of using space platforms of various types are also available.

The infrastructure required for field surveys consists of itinerant measurement (and drilling) equipment, transportation vehicles and platforms, maintenance shops operation and maintenance staff and of satellite data reception stations, when satellite data are used.

Special surveys may play a significant role in water assessment in certain regions (e.g. regions with significant snow cover or with largely unknown groundwater resources). Special surveys can be used with historical data for areal interpolation of network data, or with real-time data for water-resources operation and forecasting purposes.

3.2.2.2 Superstructure

The operation of a data collection institution requires that it has developed and/or adopted adequate techniques of measurement, and has staff of required qualifications and experience. In addition, such an institution has to have a technical organization able to operate the infrastructure and store and process the collected data in the required form for dissemination to users or input for obtaining information at measurement points or at ungauged points through models for data generalization.

3.2.2.2.1 Techniques

Techniques for collecting data on the water cycle have been described in the major guides and operation manuals of the specialized UN organizations (see references to Chapter 2). Therefore these techniques are not discussed further here.

3.2.2.2.2 Personnel

The superstructure personnel in data collection institutions consists of the staff required to plan and supervise the operation of the infrastructure, to adopt or develop techniques of measurement, quality control and to develop techniques for data storage and processing, and implement them. Superstructure staff requirements depend upon the size of the infrastructure and the type of organization. Generally total staff requirements in a country will increase from the vertical to the horizontal and complex types. As data storage and processing can be largely computerized, and quality control can be made significantly more efficient by the computer, one can expect that staff requirements will change as computer automation of these processes increases. The availability of experienced staff for computer operation, programming and interpretation of computer output must be considered when automation is introduced.

3.2.3 Evaluation elements and levels of activity

Table 3.1 presents a set of evaluation elements which may be used in considering activities relating to the collection of data. The evaluator should, as far as possible, complete this table by filling in values for the activity levels and by assigning levels of emphasis indicating the relative importance of each element. There may be some elements for which it is meaningless or impossible to make an evaluation for the area under study. In addition, elements other than these listed in Table 3.1 may be of particular local importance; in which case the evaluator should add them to the table and include them in his evaluation. This same flexible approach, placing a major degree of responsibility on the evaluator, should be followed with regard to all the tables of evaluation elements presented in the handbook.

3.2.4 Adequacy reference levels

Adequacy reference levels may cover both the infra- and superstructure. It should be borne in mind that the existence of stations per se without adequate staff, equipment, repair and maintenance facilities for the equipment and storage, processing and dissemination facilities for the data is insufficient for obtaining basic water assessment data. Furthermore, the evaluation should try to take into account the observing programme, data quality and length of record in addition to the number of stations.

Reference levels for basic water-resource data (inventory) can be obtained in practice by comparing conditions where such inventories have been satisfactory with conditions where they have not. However, it is difficult to define what constitutes a satisfactory basic WRA. For the purpose of the evaluation it is suggested that a satisfactory basic water-resource inventory may be considered to have been obtained in countries (regions) where development planning has not been delayed by the lack or gross inaccuracies of such data (Chapter 5). Reference levels for other data related to the use of water within specific developments (design, construction, operation) are difficult to establish as they depend on socio-economic conditions. In general, one can state that water-resource data for actual water use are adequate when the cost of increasing further the collection or accuracy of such data would exceed the economic benefits resulting from an increased amount of data or their increased accuracy. However, when increased accuracy of data may result in the saving of human life, other criteria may be applied. In view of adequacy criteria for water-resource data required for actual, individual development projects, these have been considered outside the scope of this project, as they cannot be applied regionally or country wide.

Reference levels for basic WRA are suggested in Appendix IV and are based partly on WMO recommendations (WMO, 1981), and preliminary checks made in some countries with adequate basic WRA. Appendix IV also indicates the emphasis which might be attached to the evaluation elements shown in Table 3.1.

3.3 Data on water-resource projects and use

3.3.1 Requirements

In addition to the measurement of the various components of the water cycle, in developed areas, basic WRA requires data on the changes introduced by man in the time and space variation of these components. These data should be used for eliminating the effects of water-resource projects and re-establishing the natural hydrological conditions that are necessary for basic WRA. In particular, data on such changes are required for:

- reconstitution of the natural regime of the water balance components to enable elimination of non-stationarity in time and space series of data and development of relationships between time series parameters and physiographic characteristics;

- assessing through physical and/or statistical models future changes in the variation of the quantity and quality characteristics of water resources due to development.

3.3.2 Data systems

Water-resource uses and related projects affect directly or indirectly all water cycle components.

Data on water-resource uses and related projects can be collected either by the organizations collecting data on the natural regime of the water cycle components, or by the users. In some countries a combined system in which both groups of institutions may be involved in various ways may be preferred. Because bias occasionally may be involved in data reported by users, when data are collected by them it is advisable to ensure that an independent system of checking these data is available.

3.3.3 Adequacy of data on water-resource uses and related projects

Projects related to water-resource uses vary in size from a simple well system which abstracts a small fraction of a groundwater resource, to large storage abstraction and diversion projects that may change completely the hydrological regime of the largest rivers of the country under consideration.

In most cases it is impossible to obtain data from absolutely all water-resource projects and a certain sampling system is required. A simple empirical rule for assessing the adequacy of a system of monitoring water-resource projects would be to assume that it is necessary to monitor all large projects in a given category and a sample of medium and small ones. Large projects should be defined in terms of their influence on the hydrologic regime. The characteristics of water-resource projects that may produce changes in the hydrologic regime are flow, storage, abstraction, diversion, and return of used water. It is suggested that a large project be considered as one for which the characteristic that produces hydrologic changes is at least larger by one standard deviation than the mean of that characteristic for projects in the given group. On this basis evaluation elements have been developed as shown in Table 3.2. This table should be completed by the evaluator to the extent possible. Appendix V presents emphasis levels which might be used in this regard.

3.4 Physiographic data

3.4.1 Data needs

Physiographic data are defined for the purpose of this project as data that are related indirectly to water resources, and should be used with hydrological and meteorological data to estimate the characteristics of the water resources.

Physiographic data are required in basic WRA for several purposes, in particular for:

- explaining the causes of variation in space and time of water cycle elements and using this for interpolation of measured water cycle data to ungauged sites;

- prediction of changes in time and space of water-resource characteristics due to water use and changes in river basin conditions;

- estimation of costs for developing water resources for certain uses.

Physiographic data for all basic WRA purposes are mainly concerned with data on topography, geology (geomorphology included), pedology, land use and land cover. However, the required level of detail (scale) of the data is different according to the purpose for which it is intended. All above-mentioned data can be considered to be invariable in time except for data on land-use/land-cover whose time variation closely influences variation in time of runoff and related water cycle elements. In addition, prediction of changes in time of water-resource characteristics requires that data on water use projects (existing and being implemented) are also available as mentioned in 3.3 above.

3.4.2 Data systems

The data systems required for basic WRA purposes are slightly different for each type of physiographic characteristic in conjunction with the particularity of the characteristic and its use in basic WRA activities.

3.4.2.1 Topographic data

These are required since topography is an explanatory factor of variation of water cycle elements, as input to almost all types of water balance models and are used for assessment of cost of developing water resources. For the first purpose the scale required usually varies between 1:250 000 to 1:1 000 000. Larger scales (e.g. 1:100 000) are required only for relatively small river studies (less than 1 000 sq km) and should not be considered necessary, in general, for country-wide assessments. However, the scale of topographic maps required for assessing the cost of development of specific water resources is between 1:25 000 and 1:50 000. These maps may also be valuable for hydrological studies, particularly those for urban flood mapping.

A very important element of the topographic maps for WRA is the river network. Topographic maps are currently obtained from combined aerial photography and ground truth data. In areas covered by dense forest it is generally very difficult to trace the river network on the basis of aerial photography and large-scale maps, ground-based surveys or other techniques should be used to complete the river network.

3.4.2.2 Geological and geomorphological data

The geomorphological conditions and the geological formations which form significant outcrops are some of the major factors which determine the runoff and infiltration coefficients and the quality of the groundwater. Geomorphological and geological data are therefore essential both for indirect estimates of surface water and groundwater characteristics and for development of various types of models for estimating surface water and groundwater characteristics.

The main geomorphological and geological data required are: the geomorphology of the river network including data on cross sections, meanders, braided channels and the like; the lithologic-stratigraphic characteristics and distribution of pervious and impervious rocks; the tectonics of the region; the hydrogeological characteristics (porosity-field capacity, permeability, transmissivity) of the water bearing layers and the geochemistry of actual and potential water-bearing layers.

3.4.2.3 Pedological data

There is in most areas a relationship between soil characteristics and the climate, primarily precipitation characteristics, the runoff, infiltration, and other hydro-meteorological characteristics. Pedological data are therefore extremely important as inputs in hydrological models of various types. The type of soil is also of significance in connection with water quality and sediment-erosion characteristics. Adequate pedological data for WRA purposes therefore include data on the type of soil, the thickness of its layers, the chemical-mineralogical composition and grain size distribution per layer, infiltration and permeability characteristics, porosity, water retention (field capacity), cohesion and erosion characteristics. In most cases all such data are not necessarily available when soil surveys are made (usually by combined remote sensing - ground truth techniques), as most surveys are carried out for agricultural-forestry purposes, and data of significance for water-resources purposes are usually obtained only in a subsidiary manner.

Except for smaller countries, appropriate scales of pedological maps for hydrological investigations vary from 1:250 000 to 1:1 000 000. A larger scale would be difficult and uneconomical to process and smaller scales would not contain the required details. However, for preliminary studies good pedological 1:5 000 000 maps might be useful.

3.4.2.4 Land-use/land-cover

Land-use/land-cover characteristics reflect in many ways to the hydrometeorological conditions of an area. Generally land-use/land-cover vary slowly in time. However, occasionally, this variation can be rapid, for example following forest fires or extensive deforestation by man. Modifications in the hydrological regime following such rapid land-use land-cover changes may be dramatic. Therefore, for obtaining inputs in hydrological models, as well as for detecting rapid modifications (non-stationarities) in the hydrological regime, it is important to update land-use land-cover maps periodically.

Convenient land-use land-cover maps that can be used in basic WRA are 1:250 000 and, when very large areas are involved, 1:1 000 000. Such maps are usually obtained through combined remote-sensing ground-truth surveys. These maps should be updated periodically, more frequently in areas subject to rapid change. This could be done, for example, by automated or manual interpretation of Landsat imagery (WMO, 1979).

3.4.3 Adequacy of physiographic data

For topographic, geological (geomorphological) and pedological data, adequacy for WRA purposes can be simply evaluated by the percentage of land area which is covered for the given country by the maps of the required type. For pedological maps the percentage of country for which hydraulic characteristics of soils can be estimated is quite important. In the case of land-use land-cover data, adequacy depends also on the interval of time between updatings of available maps.

Table 3.3 presents a set of evaluation elements to be used with regard to physiographic data. The evaluator should complete this table to the extent possible. Appendix VI presents suggested emphasis levels for use in this regard.

3.5 Data storage, primary processing and dissemination

3.5.1 Requirements

Water cycle as well as auxiliary data are usually stored, primarily processed and occasionally disseminated to other users, by the agencies that collect them. Proper storage and preservation of the data as well as consistent primary processing and data dissemination is obviously essential for adequate WRA.

3.5.2 Data storage

A full description of recommended procedures for storage and primary processing of water cycle data is given in WMO (1981) and Unesco/WHO (1977).

3.5.2.1 Storage of water cycle data

These can be stored in the form of original data sheets (observer's booklet, level recording log sheets, etc.) in microfilm form, or in computer compatible form (CCF). The adequacy of the storage system can be evaluated by means of two basic characteristics: probability of full preservation of all original data and the time required to locate specific data. Time required to locate data stored in CCF usually takes only a few seconds for on-line storage systems to a few hours for off-line storage systems. Data in CCF are also exposed to aging and conservation measures have to be taken accordingly.

3.5.2.2 Storage of physiographic data

Data on the operation of water-resource projects are collected and usually stored in a similar manner to water cycle data. However, such data are usually stored by the user and frequently this makes it difficult to retrieve them.

Conventional topographic, geologic and pedologic data represent relatively limited volumes that can be preserved in original form or on microfilm. Data preservation as well as locating specific data may present difficulties in such cases. Additional difficulties are encountered with this storage system when it is attempted to check the data for consistency or to merge them for various purposes. As more and more topographic, geologic, pedologic and land-use land-cover data are collected using automated equipment, particularly by remote sensing, it is convenient and efficient to store these data in CCF and also to transpose conventional data to the same form.

3.5.3 Primary processing

Primary processing consists of two basic operations: the first is cataloguing and banking of data, the second is preparation of user oriented data. Both operations are discussed in detail in WMO (1981) and Unesco/WHO (1977).

3.5.3.1 Data cataloguing

This requires establishing an efficient inventory of the data under consideration to enable an evaluation of the extent of data availability and rapid data retrieval. Although there are some basic differences between time series of data, most of which represent water cycle data, and space series of data, most of which represent physiographic data, both could best be catalogued by means of a system of identifying each datum in a common system of "co-ordinates". Such co-ordinates could conveniently be selected as the subject (type of data), object (to which the data refer), time, space, data quality and source. A system of cataloguing that enables locating the data only with respect to some of the above co-ordinates is usually inefficient.

3.5.3.2 Conventional data banks

Catalogued water cycle or physiographic data, accessible through all six co-ordinates (see 3.5.3.1) or at least through the subject-object-space-time co-ordinates to all data users constitute a conventional data bank. In the case of horizontal or complex organizations, at least one of the institutions involved in the collection of a type of data is required to have all catalogues pertaining to this type of data as a basis for a corresponding conventional bank of such data.

3.5.3.3 Computerized data banks

Computerized water cycle and auxiliary data makes the work of both data collecting and data using agencies much more efficient. Computerized banks of auxiliary data provide, in addition to increased efficiency, the possibility of applying many types of models for the interpolation of water cycle data.

The first, simplest and most important step in computerizing a water cycle or auxiliary data bank consists in computerizing the catalogues of data. This enables one to search for data according to any one of the six "dimensions" mentioned in 3.5.3.1. The data proper are then transposed to CCF gradually, as needed.

Checking for data entry errors is a very important element in a computerized bank and should receive utmost priority. Of course, some checks can be done also for conventional data banks. However, this requires more manpower. In the case of physiographic data, checks can be done by overlaying maps of related data (e.g. soil and surface geology and topographic maps).

3.5.3.4 Preparation of user oriented data

This relates to the extraction of pertinent data from original records and to the elementary processing for consistent presentation to users. It is a very important step in basic WRA activities, as some of the collected data may be useless or misleading without it (WMO, 1981, Unesco/WHO, 1977).

3.5.4 Publications

Publication of water cycle data is usually in the form of monthly bulletins, yearbooks and longer-term summaries, including both tables and maps. Publications issued at regular intervals usually contain primary processed data (3.5.3) and their format follows certain established guidelines which are described in detail in WMO (1981) and Unesco/WHO (1977). Various reports and bulletins may be published to meet the requirements of specific users and can complement the regular publications.

Physiographic data are usually published in the form of maps, less frequently in tabular form (e.g. tables of areas of various land uses, types of soil, soil characteristics, etc.). More recently, interpreted aerial photographs and imagery have been used for publishing auxiliary data of interest in WRA. Pedological and hydrogeological maps are usually published in the framework of reports on the studies that lead to the given maps. Such studies are of great significance when pedological and hydrogeological maps are used.

3.5.5 Adequacy of data storage, primary processing and dissemination

Table 3.4 presents a series of evaluation elements to be used in estimating the adequacy of data storage, primary processing and publication activities. They are based on the considerations discussed below.

The ratio between the total number of data stored and data collected, excluding data lost and discarded, is a general indication of the efficiency of a survey. Another indicator of the data collection efficiency is the ratio between data lost (gaps on records) and discarded (because of gross errors, etc.) and actual data collected (i.e. excluding the above).

An important characteristic of the preservation reliability of the data storage system is the ratio between the number of data with back up (data stored in two different places unlikely to be involved in common cause accidents) and the total number of data stored.

Type of storage (original, microfilm, CCF) and related duration of locating specific data are also important indexes of the efficiency of the survey.

Availability of Landsat repetative imagery (photographic or in CCF) may become in time a significant input in basic WRA.

The existence and extent of coverage of catalogues including all "co-ordinates" is a significant criterion of the level of accessibility of the data. This is important for both water cycle data and auxiliary data and the first step required for creation of a data bank.

In proposing indexes for assessing adequacy of data banks the following considerations are used:

- where computerization of data banks is beyond the country's means or when it is not needed, conventional data banks are essential for a smooth flow of data; indexes that may characterize such data banks are the percentages of data included and the lag time between a request for data and the actual locating of the data;

- where computerized data banks are introduced the indexes should not be related to the current number of data stored and/or available programmes, or even to lag time between request of a document (data) and actually obtaining it, but rather to the training-experience of the computerized data bank staff and the computer capacity (memory) and relevant peripherals.

The extent to which collected data have been prepared for user oriented presentation is also an indication of the efficiency of the data collection systems evaluated. As errors in daily flow estimates which are part of this preparation are very important for basic WRA, and as such errors are difficult to assess, an index of these errors is proposed. This is the ratio between the range of levels for which flow measurements have been carried out to the total recorded range of levels. A similar evaluation element is proposed for water quality.

Publication of a minimum suite of data on the water cycle provides the best means to inform a large number of users on data availability and on the data themselves, and their timely publication increases their usefulness.

The evaluator should, as far as possible, complete Table 3.4, Appendix VII offering proposals as to the emphasis levels which might be used.

References to Chapter 3

Unesco (1977) - Groundwater Studies: An International Guide for Research and Practice. Studies and Reports in Hydrology No. 7, Paris.

Unesco/WHO (1977) - Water Quality Surveys, Studies and Reports in Hydrology No. 23, Paris.

WMO (1981) - Guide to Hydrological Practices, WMO - No. 168, Geneva.

WMO (1979) - Application of Remote Sensing to Hydrology, WMO - No. 513, Geneva.

Table 3.1. COLLECTION OF BASIC DATA

EVALUATION ELEMENT	EMPHASIS* AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
Precipitation stations; non-recording (Number per 10^4 km^2)								
Precipitation stations: recording (Number per 10^4 km^2)								
Evaporation stations; non-recording (Number per 10^5 km^2)								
Evaporation stations; recording (Number per 10^6 km^2)								
Snow courses; conventional (Number per 10^4 km^2)								
Stations measuring water quality of liquid and solid precipitation (Number per 100 precipitation and snow courses)								
Meteorological satellite receiving stations (Number per 10^6 km^2)								
Surface water level stations; non-recording (Number per 10^4 km^2)								
Surface water level stations; recording (Number per 10^4 km^2)								

* L = Low emphasis
M = Medium emphasis
H = High emphasis

Table 3.1. COLLECTION OF BASIC DATA (contd.)

EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
River discharge stations: (a) (Number per 10^4 km^2)								
Sediment discharge stations (Number per 10^4 km^2)								
Surface water temperature stations (Number per 10^4 km^2)								
Water quality of surface water (Number per 10^4 km^2)								
Groundwater level stations; non-recording (Number per 10^4 km^2)								
Groundwater level stations; recording (Number per 10^5 km^2)								
Groundwater stations measuring hydraulic characteristics (Number per 10^4 km^2)								
Groundwater quality stations (Number per 10^5 km^2)								
Repair and maintenance shops for meteorological equipment (Number per 200 precipitation stations)								

Table 3.1. COLLECTION OF BASIC DATA (contd.)

EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
Current meters (Number per 10 discharge stations)								
Rating facilities for current meters (Number per 200 current meters)								
Repair and maintenance shops for hydrological equipment (b) (Number per 200 discharge stations)								
Water sediment laboratories (Number per 100 sediment stations)								
Water quality laboratories (Number per 100 water quality stations)								
Well drilling sets (Number per 10^6 km^2)								
Repair and maintenance shops for well drilling sets (b) (Number per 10 well drilling sets)								
Meteorological station observers (Number per precipitation station)								
Water level observers (Number per water level stations)								
Inspectors of meteorological stations (Number per 100 precipitation stations)								
Hydrological field teams (2-3 persons) (Number per 10 discharge stations)								

Table 3.1. COLLECTION OF BASIC DATA (contd.)

EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
Special survey teams surface water (3-4 persons) (Number per 10^5 km^2)								
Special survey teams ground water (3-4 persons) (Number per 10^5 km^2)								
Superstructure staff meteorology (Number per 100 precipitation stations)								
Superstructure staff surface water (Number per 100 river discharge stations)								
Superstructure staff groundwater (Number per 100 groundwater monitoring stations)								

(a) These are either non-recording or recording surface water level stations where streamflow measurements are made.

(b) Two or three of these repair shops may be combined into a dual or multipurpose repair shop.

NOTES:

1) In addition to dividing the country into regions according to climate, aridity and type of surface geology, countries which are well assessed in certain limited areas only should be divided, before completing the above table, into well assessed regions and others, and a separate table should be completed for each area. This is valid even if the assessment is satisfactory only for one or several elements of the water cycle.

2) The evaluation should take into consideration the possibility of the same staff being responsible for a number of different tasks, and/or the use of sophisticated technology permitting a reduction of staff.

3) The rows corresponding to groundwater elements can be subdivided into phreatic and deep groundwater.

4) Appendix IV presents suggested emphasis levels and reference levels for use in conjunction with this table.

TABLE 3.2 - AVAILABILITY OF DATA ON WATER-RESOURCE PROJECTS

TYPE OF DATA ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Large water-resource projects	Percentage of storages surveyed				
	Percentage of abstractions surveyed				
	Percentage of diversions surveyed				
	Percentage of returns of polluted water surveyed				
Medium and small water-resource projects	Percentage of storages surveyed				
	Percentage of abstractions surveyed				
	Percentage of diversions surveyed				
	Percentage of returns of polluted water surveyed				

Notes:

1) Using even approximate estimates of the total number of storages, abstractions, diversions and returns, evaluate the percentages of these for which data and information are available which could be used to assess the impact of the projects on the hydrological regime.

2) Appendix V presents suggested emphasis levels for use in this table.

TABLE 3.3 - PHYSIOGRAPHIC DATA

TYPE OF DATA ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Topographic	Percentage of area covered by 1:1 000 000 maps				
	Percentage of area covered by 1:250 000 maps				
	Percentage of area for which river network checked on ground or with special technique				
Geological and geomorphological	Percentage of area covered by 1:1 000 000 maps				
	Percentage of area covered by 1:250 000 maps				
	Percentage of area for which piezometric levels available				
	Percentage of area for which hydrogeochemical characteristics available				
	Percentage of area for which hydraulic parameters available				
Pedological	Percentage of area covered by 1:1 000 000 maps				
	Percentage of area covered by 1:250 000 maps				
	Percentage of area for which hydrogeochemical characteristics of soils can be estimated				

TABLE 3.3 - PHYSIOGRAPHIC DATA (contd.)

TYPE OF DATA ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Land-use Land-cover	Percentage of area covered by 1:1 000 000 maps				
	Percentage of area covered by 1:250 000 maps				
	Percentage of area covered by updated (biennially) maps				

Notes: 1) Indicate map accuracy wherever available. Consistency of maps, particularly of their backgrounds, for various scales and types of maps may constitute an additional evaluation index.

2) Appendix VI presents suggested emphasis levels for use in this table.

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
DATA STORAGE AND CATALOGUING					
Water cycle data					
Meteorological and hydrological	Percentage stored as originals				
	" " on microfilms				
	" " in CCF				
	" " in duplicate				
	" lost or not stored				
	" fully catalogued[1)]				
	Time required to locate a specific datum				
Hydrogeological	Percentage stored as originals				
	" " on microfilms				
	" " in CCF				
	" " in duplicate				
	" lost or not stored				
	" fully catalogued[1)]				
	Time required to locate a specific datum				
Physiographic data					
Topographical	Percentage stored as originals				
	" " on microfilms				
	" " in CCF				

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Topographical (contd.)	Percentage lost or not stored				
	" fully catalogued[1]				
	Time required to locate a specific datum				
Geological and geomorphological	Percentage stored as originals				
	" " on microfilms				
	" " in CCF				
	" lost or not stored				
	" fully catalogued[1]				
	Time required to locate a specific datum				
Pedological	Percentage stored as originals				
	" " on microfilms				
	" " in CCF				
	" lost or not stored				
	" fully catalogued[1]				
	Time required to locate a specific datum				
Land-use/land-cover	Percentage stored as originals				
	" " on microfilms				
	" " in CCF				

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Land-use/land-cover (contd.)	Percentage lost or not stored				
	" fully catalogued[1)]				
	Time required to locate a specific datum				
	Landsat imagery available (photo and CCT's)				
CONVENTIONAL DATA BANKS					
<u>Water cycle data</u>					
Meteorological	Percentage of data included				
	Lag between request and receipt of data				
Hydrological	Percentage of data included				
	Lag between request and receipt of data				
Hydrogeological	Percentage of data included				
	Lag between request and receipt of data				
<u>Physiographic data</u>					
Topographical	Percentage of data included				
	Lag between request and receipt of data				
Pedological	Percentage of data included				
	Lag between request and receipt of data				
Geological and geomorphological	Percentage of data included				
	Lag between request and receipt of data				
Land-use/land-cover	Percentage of data included				
	Lag between request and receipt of data				

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
COMPUTERIZED DATA BANKS[2)]					
Water cycle data					
Meteorological	Computer types, core memories and peripherals (list separately)				
	Programmers (number)				
	Average no. of years of education and experience				
Hydrological	Computer types, core memories and peripherals (list separately)				
	Programmers (number)				
	Average no. of years of education and experience				
Hydrogeological	Computer types, core memories and peripherals (list separately)				
	Programmers (number)				
	Average no. of years of education and experience				
Physiographic data					
Topographical	Computer types, core memories and peripherals (list separately)				
	Programmers (number)				
	Average no. of years of education and experience				
Pedological	Computer types, core memories and peripherals (list separately)				
	Programmers (number)				
	Average no. of years of education and experience				

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Geological and geomorphological	Computer types, core memories and peripherals (list separately)				
	Programmers (number)				
	Average no. of years of education and experience				
Land-use/land-cover	Computer types, core memories and peripherals (list separately)				
	Programmers (number)				
	Average no. of years of education and experience				
PRIMARY PROCESSING					
<u>Water cycle data</u>					
Meteorological	Percentage recording charts digitized				
	Percentage daily computations carried out				
Hydrological	Percentage recording charts digitized				
	Percentage daily flows estimated				
	Ratio of range of levels of flow measurement to total range				
	No. of sediment laboratories				
	No. of water quality laboratories				
Hydrogeological	Percentage recording charts digitized				
	Percentage 1-3-5 days regular observations				
	Percentage temperature and water quality observations				

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
<u>Physiographic data</u>					
Topographical	Percentage area with aerial photography for which contours have been traced				
Pedological	Percentage area for which field work has been processed				
Hydrological	Percentage area for which field work has been processed				
Land-use/land-cover	Percentage imagery (including Landsat) for which rectification and interpretation have been carried out				
PUBLICATIONS					
<u>Water cycle data published regularly</u>					
Meteorological	Publication interval (months)				
	Publication lag (months)				
Hydrological	Publication interval (months)				
	Publication lag (months)				
Hydrogeological	Publication interval (months)				
	Publication lag (months)				

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
<u>Physiographic data</u>					
Topographical[3]	Topographic maps				
	1:1 000 000 maps published				
	Total area				
	Percent of country				
	Publication lag				
	1:250 000 maps published				
	Total area				
	Percent of country				
	Publication lag				
Pedological	Pedological maps				
	1:1 000 000 maps published				
	Total area				
	Percent of country				
	Publication lag				
	Studies of 1:1 000 000 maps				
	yes/no				
	Percent of country				
	1:250 000 maps published				
	Total area				
	Percent of country				
	Publication lag				
	Studies of 1:250 000 maps				
	yes/no				
	Percent of country				

TABLE 3.4 - DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
<u>Physiographic data</u>					
Geological and hydrogeological	Geological and hydrogeological maps				
	1:1 000 000 maps published				
	Total area				
	Percent of country				
	Publication lag				
	Studies of 1:1 000 000 maps				
	yes/no				
	Percent of country				
Land-use/land-cover	Land-use land-cover maps				
	1:1 000 000 maps published				
	Total area				
	Percent of country				
	Publication lag				
	Studies of 1:1 000 000 maps				
	1:250 000 maps published				
	Total area				
	Percent of country				
	Publication lag				
	Studies of 1:250 000 maps				
	yes/no				
	Percent of country				

Notes: 1) Fully catalogued data means data that can be located according to object, subject, space, time, quality and source.

2) If one computer is used for a number of water cycle components and/or types of auxiliary data, this should be stated and the data completed only for one water cycle component or type of auxiliary data.

3) Topographic maps 1:50 000 and 1:10 000 may be included depending on size of the country and also for particular hydrological studies (i.e. urban flood mapping).

4) Appendix VII presents suggested emphasis levels for use in this table.

4. AREAL ASSESSMENT OF HYDROLOGICAL ELEMENTS

4.1 Need for areal assessment

Basic WRA is carried out essentially through a network of stations. However, data on hydrological elements are necessary for basic WRA (inventory, planning, and other various purposes) not only at the gauging stations, but at innumerable other ungauged locations. Such data can be estimated by combining the data measured at the gauging stations with physiographic data in the framework of data interpolation or data transfer techniques. Auxiliary data consist normally of physiographic data and, for a given type of data on a given water balance component, data obtained on other components. Such techniques consist primarily of mapping and modelling and less sophisticated methods such as linear interpolation. The adequacy of such interpolation techniques is related to the accuracy of the estimates. This in turn depends upon the density of network stations, their distribution, the accuracy of the measured data, the interpolation technique used, and the availability and accuracy of the physiographic data required. In general, the accuracy of the estimate varies, for a given technique and given related data, with the density of the network stations. By comparing relationships between accuracy of estimate and network density for various techniques, the adequacy of the models and implicitly of the related physiographic data can be evaluated.

4.2 Surface water

The water balance components that are commonly interpolated for WRA purposes are the characteristics of precipitation and runoff. Actual and potential evaporation is also frequently mapped for hydrological and other purposes. Areal variation of long-term values are most frequently required, but seasonal or event-related areal variation is often also needed. Areal variation of statistical characteristics of precipitation and runoff is also widely used. Water quality is less frequently interpolated in practice, although the techniques for such interpolation are, in principle, the same as for water quantity, at least for a number of parameters.

4.2.1 Mapping

Techniques for hydrological and meteorological mapping have been discussed in detail in Unesco/WMO (1977) and in WMO (1972). Mapping of hydrological parameters using conventional techniques (isolines) takes only partial advantage of the physiographic data, such as topography and pedology, to the extent to which they are considered as background indicators in tracing the isolines. Computerized mapping, for example, by the square grid technique (WMO, 1972, WMO/UNDP, 1979), provides the advantage of objective use of the physiographic data.

4.2.2 Models

WMO (1975) describes a series of so-called deterministic and statistical models that relate precipitation to runoff and which permit synthesis of time series of flow and, in the case of deterministic models, other water balance components such as soil moisture and groundwater, at a gauged site for which the model has been calibrated. Numerous kinds of models have been reported in the literature. Because of their capability of synthesizing groundwater characteristics, deterministic models represent a preferred technique where simultaneous areal assessment of surface and groundwater is required. Models are also important for estimating flood discharge and levels from extreme precipitation data.

4.2.3 Other techniques

These may vary from methods based on multiple regression and regionalization using hydrologic, climate and catchment characteristics to the simple linear interpolation of these characteristics in a very densely gauged area. As with other interpolation techniques, the sole criterion of adequacy is the accuracy of the results obtained, estimated through validation.

4.3 Groundwater

Data that are most frequently interpolated for the assessment of groundwater resources are related to hydrogeological indexes (Unesco, 1972), identification of aquifer systems and hydraulic parameters with definable space variation. Water levels and hydrogeochemical characteristics often vary in time and space and their interpolation is difficult. As for surface water, both mapping and modelling techniques can be used.

4.3.1 Mapping

Techniques of hydrogeological mapping have been discussed in detail in Unesco/WMO (1977). Currently, Unesco also co-ordinates the publication of consistent hydrogeological maps of Europe, South America and the Arab States (Unesco, continuous). A hydrogeological map of Africa is being developed through an OAU/ECA project.

Maps can be used to represent hydrogeological indexes, specific hydrogeological characteristics such as transmissivity, depth of the groundwater table, or specific groundwater yield. The latter is of great significance, as it provides a basis for groundwater resource assessment on a regional or countrywide scale.

4.3.2 Models

Three types of models have been used in practice for groundwater modelling. The first type uses the similarity between the electrical and groundwater flow fields and has been generally used for the solution of limited local problems. The second type is based on hydraulic-mathematical analysis of the water balance and water flow in the ground. The third is based on time-series analysis of data records, in a similar manner as for surface water records. The hydraulic-mathematical analysis can be used for the solution of both water quantity and quality problems, and can be coupled with similar water surface models to provide a comprehensive analysis of the water resources of a region.

4.4 Adequacy of areal assessment

This can be evaluated from the percentage area of country (region) for which maps and models that can and/or have been used for data interpolation are available, and from the corresponding relative error of estimate. Simple interpolation techniques are not considered since these would be adequate only in very limited areas (see Section 4.2.3).

Table 4.1 presents the evaluation elements to be used for assessing the adequacy of WRA from the viewpoint of areal interpolation. In setting up these indexes the following points have been considered:

- from the viewpoint of water-resource inventory it is important to know the areal distribution of mean precipitation, runoff, soil moisture and groundwater yield, the seasonal variation of these, and their statistical characteristics that enable data synthesis at ungauged sites;

- the above can be obtained mainly through mapping and/or through deterministic or statistical modelling. For modelling it is important to have the required inputs in order that they are useful for the purposes of basic WRA;

- for estimates of extreme flood events is important to have data on extreme precipitation and adequately calibrated models;

- for all interpolated data the final criterion of adequacy is the error of validation, for example, the error obtained by random split sampling. It is not advisable to use a map or model that has not been evaluated on such a basis, as the map or model may represent the results of an excessive fitting exercise, that has no value for interpolation purposes.

Table 4.1 may be divided so as to present the information on models and modelling in a separate table. As a number of different models are often used for different purposes, it may be useful to list each model separately. The evaluator should as far as possible complete Table 4.1. Appendix VIII presents suggestions as to the emphasis levels that might be used for this purpose.

References to Chapter 4

Unesco (1972) - Groundwater Studies - An International Guide for Research and Practice, Studies and Reports in Hydrology No. 7, Paris.

Unesco/WMO (1977) - Hydrological Maps, Studies and Reports in Hydrology No. 20, Paris.

WMO (1972) - Casebook on Hydrological Network Design Practice, WMO - No. 324, Geneva.

WMO (1975) - Intercomparison of Conceptual Models used in Operational Hydrological Forecasting, Operational Hydrology Report No. 7, WMO - No. 429, Geneva.

TABLE 4.1 - AREAL ASSESSMENT

TYPE OF ACTIVITY EVALUATED	EVALUATION ELEMENT*	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Meteorological	Area for which annual isohyetal maps are available (% of total area)				
	Validation error %				
	Area for which seasonal isohyetal maps are available (% of total area)				
	Validation error %				
	Area for which maps of statistical parameters of annual precipitation are available (% of total area)				
	Validation error %				
	Area for which maps of statistical paramaters of seasonal precipitation are available (% of total area)				
	Validation error %				
	Area for which maps of statistics of storm precipitation are available (% of total area)				
	Validation error %				
Hydrological	Area for which annual runoff map available (% of total area)				
	Validation error %				
	Area for which seasonal runoff map available (% of total area)				
	Validation error %				
	Area for which maps of statistical parameters of annual runoff available (% of total area)				
	Validation error %				

TABLE 4.1 - AREAL ASSESSMENT (contd.)

TYPE OF ACTIVITY EVALUATED	EVALUATION ELEMENT*	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Hydrological (contd.)	Area for which maps of statistical parameters of seasonal runoff available (% of total area)				
	Validation error %				
	Area for which rainfall-runoff models have been calibrated (% of total area)				
	Validation error %				
	Area for which inputs to rainfall-runoff models are available (% of total area)				
	Validation error %				
	Area for which maps of annual soil moisture available (% of total area)				
	Validation error %				
	Area for which seasonal soil moisture maps available (% of total area)				
	Validation error %				
	Area for which annual groundwater yield maps available (% of total area)				
	Validation error %				
	Area for which seasonal groundwater yield maps available (% of total area`				
	Validation error %				
	Area for which groundwater models have been calibrated (% of total area)				

TABLE 4.1 - AREAL ASSESSMENT (contd.)

TYPE OF ACTIVITY EVALUATED	EVALUATION ELEMENT*	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Hydrological (contd.)	Validation error %				
	Area for which inputs to groundwater models are available (% of total area)				
	Area for which relationships between time series parameters and physiographic characteristics available (% of total area)				
	Validation error %				
	Area for which inputs into relationships between time series parameters and physiographic characteristics available (% of total area)				

* Validation error is defined as the error obtained, for example, by split sample testing. In this the available data sample is split into two. One sample is used to calibrate the model (e.g. to trace the isohyets) and the other sample is used to estimate the errors as the difference between measured and estimated (e.g. from the isohyets).

Note: Appendix VIII presents suggested emphasis levels for use in this table.

5. HYDROLOGICAL DATA AND INFORMATION REQUIRED FOR PLANNING PURPOSES

The basic WRA programme is considered adequate if all its three components (data networks, auxiliary data and interpolation techniques) are available and sufficiently accurate to supply the water-resources information required for planning purposes at any point of the assessment area (see Section 1.4).

Thus, although basic WRA is concerned only with the supply aspect of the water supply-demand equation, evaluation of the adequacy of the basic WRA programme requires that consideration be given to the use which is made of the data for water-resource planning purposes.

This chapter provides general indications as to the type of data required for various projects, particularly for various typical project elements, and the required accuracy of the data in terms of project components. It also calls for consideration of which type of data is more important for various project components. It is not proposed that a comprehensive study be made of the requirements of each individual project. The evaluator will be required to define only the types of projects, together with their typical elements, that may be expected to be included in the future water-resource plan. This will enable him to judge whether the type of data collected and their accuracy is adequate for planning purposes, which is a very important conclusion to be obtained from the evaluation of the basic WRA programme.

5.1 Types of water-resource data and information required for planning purposes

The types of water-resource data required for planning water-resources projects vary according to the characteristics of the project and of the water resource involved. Depending on the nature of the project, the planning of such a project may require any combination of the following data and information:

Precipitation: data on maximum precipitation with various probabilities or return periods and storm characteristics; time series of daily precipitation; precipitation statistics; areal distribution of precipitation for various months, seasons, etc.; time series of snow depth and water contents including snow accumulated on the ground (plus probability of maximum snow accumulations); temperature, radiation and humidity data; time series of water quality determinants;

Evaporation: time series of pan evaporation and of meteorological data required for estimation of evaporation, particularly solar radiation, air temperature, humidity and wind;

River and lake levels: time series of daily (occasionally hourly or instantaneous) levels, daily and/or instantaneous maximum and minimum levels with various probabilities; hydrographs of flood levels for various probabilities or return periods;

River flows: time series of daily (occasionally hourly) flows; daily and/or instantaneous maximum and minimum flows with various probabilities;

Sediment: time series of daily concentrations and/or total sediment discharge;

Water quality: time series of water quality determinants; relationship between flow and parameters of water quality;

River channel characteristics: variation of area, width and depth with level (flow); water velocity; slope;

Groundwater: time series of groundwater levels and yield estimates, and of water quality determinants.

Water-resource projects are extremely varied in nature and may present a large variation both in size and complexity and consequently a large variation in the type of data required. Nevertheless all these projects can be considered to consist of a number of typical project elements which, when grouped in accordance with specific local requirements and objectives, generate the given project. The types of water-resource data required by project elements are easier to define than for the whole project. The project elements can be grouped into structural and non-structural elements.

The main structural elements are:

(a) Modifiers of the water balance components (increasing or decreasing runoff, precipitation, evaporation, soil moisture, through surface treatment, cloud seeding, etc.);

(b) Redistribution of water in space (water collection, transportation and distribution, canals and pipes, intakes, outlets);

(c) Redistribution of water in time (surface and sub-surface reservoirs and other water storage structures);

(d) Extractors or suppliers of water energy (turbines and pumps);

(e) Water confinors (dams, dykes, flood walls, flood-proofing structures, etc.);

(f) Water relievers (spilling facilities);

(g) Quality improvers at source (reduction of soil erosion, salinization, etc.);

(h) Quality improvers at point of use (water supply and sewage treatment plants, cooling towers and lagoons, etc.).

The main non-structural elements are:

(i) Water-resource related legislation and standards;

(j) Zoning (for flood management, preservation of water resources, runoff and soil erosion management, wild life and fish habitat protection, etc.);

(k) Insurance (in relation to flooding of permanent or temporary structures (cofferdams), non-performance, accidents and disasters);

(l) Flow and level forecasting (flood forecasting and warning, operation of reservoirs, etc.).

Although occasionally information on all the characteristics of the pertinent water resource is of significance for a given water-resource project element, a number of characteristics are normally extremely important for it, others are only moderately important and others are of no interest at all. For example, for water relievers, information on maximum flow is of extreme importance, information on sediment characteristics (which may block gates) is of moderate importance, and information on minimum flows is not relevant at all. Although the emphasis or significance of each water-resource characteristic for a given element may vary with local conditions (and may also vary in time), it is possible to indicate which characteristics can be assigned high or moderate emphasis for the various elements of water-resource projects. Proposals in this regard are presented in Appendix IX.

If the type of projects expected to be included in the water-resource plan and the corresponding typical elements are known or could be anticipated, it is possible to complete Table 5.1 indicating the types of water-resource data required. This can be used in assessing whether the basic WRA programme is emphasizing the correct water-resource characteristics.

Detailed indications on the water-resource data requirements for various water-resource projects and on the manner in which the hydrologic and other water-resource data are used in determining the main dimensions of water-resource projects are described in detail in Unesco (1982).

5.2 Data accuracy

The accuracy of the data determines their usefulness for planning purposes. If the standard error of estimate of a water-resource characteristic used for planning is very large it is sometimes not possible to decide whether or not to include or exclude a given project in the development plan. Of course, the critical accuracy percentage level depends upon the type of project element, and the ratio between the estimated mean value of the characteristic and the corresponding dimension of the project. Thus for example, if a one cubic metre diversion has to be made from a river whose minimum flow with a probability level acceptable to the planner is 2000 m^3/s, an error of even 90% in estimating the minimum flow is not significant. However, if a hydroelectric plant is to be built on a river with a fully regulated flow of, say, 100 m^3/s and the margin of financial return is only 15% per year, an error of 10-15% cannot be tolerated in estimating this mean flow.

Although each project and project element has its particular tolerance limits for the error of each pertinent hydrological characteristic, it is possible to indicate approximate tolerance limits for various project elements based on experience and the consideration of the inherent error characteristics of the data. In the context of the evaluation, these tolerance limits play the role of reference levels. Suggested values for these tolerance limits/reference levels are given in Appendix IX. The values suggested take into account that the error of an individual measurement of hydrologic data varies between 2% (for mean values) to 20-30% (for extreme values), that precipitation data normally have measurement errors of 5 to 20% and that in most cases errors of interpolation affect the estimates at some project sites. The values shown in Appendix IX could therefore be used to set adequacy targets for interpolated meteorological and hydrological data but should not be construed as applicable to specific individual projects and/or particular hydrological characteristics at individual gauging stations.

5.3 Data adequacy

The evaluation of the adequacy of the WRA programme from the viewpoint of requirements for WRP is carried out by establishing whether or not the data required for planning purposes in the study area are being obtained and if their accuracy is satisfactory for planning purposes. This can be done with the help of Table 5.1.

The evaluator should complete Table 5.1 for all project elements included in any of the projects which make up the current and future water-resource plan for the area under consideration. The levels of emphasis to be entered in this table are the relative significance or importance of each water-resource characteristic for each of the pertinent project elements. The activity levels to be entered are the errors with which the particular water-resource characteristic can be determined.

It will not be easy to provide the required estimates of error. The values finally used to complete the table should be based as far as possible on objectively derived measures of likely error, but in many cases they will be based, at least in part, on the personal judgement and experience of the hydrologists, engineers and planners involved in such projects. Despite these difficulties, a major effort should be made by the evaluator to complete Table 5.1 to the maximum extent possible.

An analysis of the completed tables in comparison with the appropriate reference levels (tolerance limits) will indicate the extent to which data requirements are being met. Table 5.1 can therefore be used as an aid to the design of a new, or the improvement of an existing, WRA programme with respect to its scope and to provide guidance with respect to the required qualitative improvement in data collection and interpolation techniques. Where sites of future projects have already been clearly identified, gauging stations at the sites and improvements in data collection and measurement techniques are primarily required. Where the location of future projects is in doubt, in addition to a generally denser network, better interpolation techniques should be considered as having a very high priority.

TABLE 5.1 - USE OF WATER-RESOURCE DATA FOR PROJECTS

Water resource project element \ Water-resource characteristics	Precipitation				Evaporation	River water levels			River flow				Channel char.			Sediment	Groundwater			
	Storms	Time Series	Snow	Quality		Time Series	Max.	Min.	Time Series	Max.	Min.	Quality	Cross section	Slope	Vel. distr		Levels	Yield	Hydr. char.	Quality
Modifiers of water balance																				
Redistributors of water in space																	*	*	*	*
Redistributors of water in time																	*	*	*	*
Extractors or sup-pliers of water energy																	*	*	*	*
Water confinors																				
Water relievers																				
Quality improvers at source																	*	*	*	*
Quality improvers at use points																	**	**	**	**
Water related legis-lation and standards																				
Zoning																				
Insurance																	*			
Flow and water quality fore-casting																	*	*	*	

* If project or element deals specifically with groundwater; ** If treated water infiltrates or is pomped into the ground.

Notes: 1) The elements of water-resource projects (first column of this Table) are described in Section 5.1.

2) The activity levels (errors) are to be expressed as percentages, except for water level where they are to be presented in centimetres.

3) The values shown could be used to set adequacy targets for interpolated meteorological and hydrological data but should not be construed as applicable to specific individual gauging stations.

4) Appendix IX presents proposals as to the emphasis levels and reference levels which may be used in conjunction with this table.

Reference to Chapter 5

Unesco (1982) - Methods of hydrological computation for water projects, Studies and Reports in Hydrology No. 38, Paris.

6. MANPOWER, EDUCATION AND TRAINING

6.1 Introduction

Correct water-resource assessment can only be achieved with adequate manpower: adequate both quantitatively and qualitatively at all necessary levels and for all specializations. Manpower can be called adequate if it can execute, with sufficient competence and speed, the tasks for which it is hired.

There are many possible ways of classifying manpower levels. A very simple one is given in Figure 6.1 which makes a distinction between professionals, technicians and auxiliary personnel and observers. The technician level is subdivided into senior and junior technicians. The system in Figure 6.1 is based on differences in educational requirements, and, because the situation may be different in the various countries, should be regarded only as an example.

Although accurate surveys in this field are not available, it is clear that in the majority of the developing countries there is a shortage of water-resource manpower at all levels and in particular at the middle and lower levels.

A consideration of educational needs should cover all educational levels, including for example the training of technicians, undergraduate and post-graduate courses and continuing education. They should be based on criteria such as the actual and potential water-resource problems in an area, the available manpower qualified to deal with these problems, and existing educational and training facilities. Conclusions should be drawn on the type and size of institutions required, on appropriate curricula and syllabi, on the numbers of teachers and their special skills, and on the physical facilities, including teaching aids, that will be needed.

All available information points to the fact that at this stage the most crucial problem in this regard in the majority of developing countries is the absence or insufficiency of training facilities and in-service training programmes at the middle-level technician (sub-professional) level. Unlike professional hydrologists and water-resource engineers, whose tasks and educational requirements are more or less similar in most countries, Unesco (1974, 1983), working and educational requirements for technicians may differ greatly from one region or country to another. As it is preferable, therefore, to train technicians in their home countries, the problem of training such technicians may be more difficult than that of training professional hydrologists and water-resource engineers. International organizations can be of particular help in the training of teachers and by publishing suitable training material.

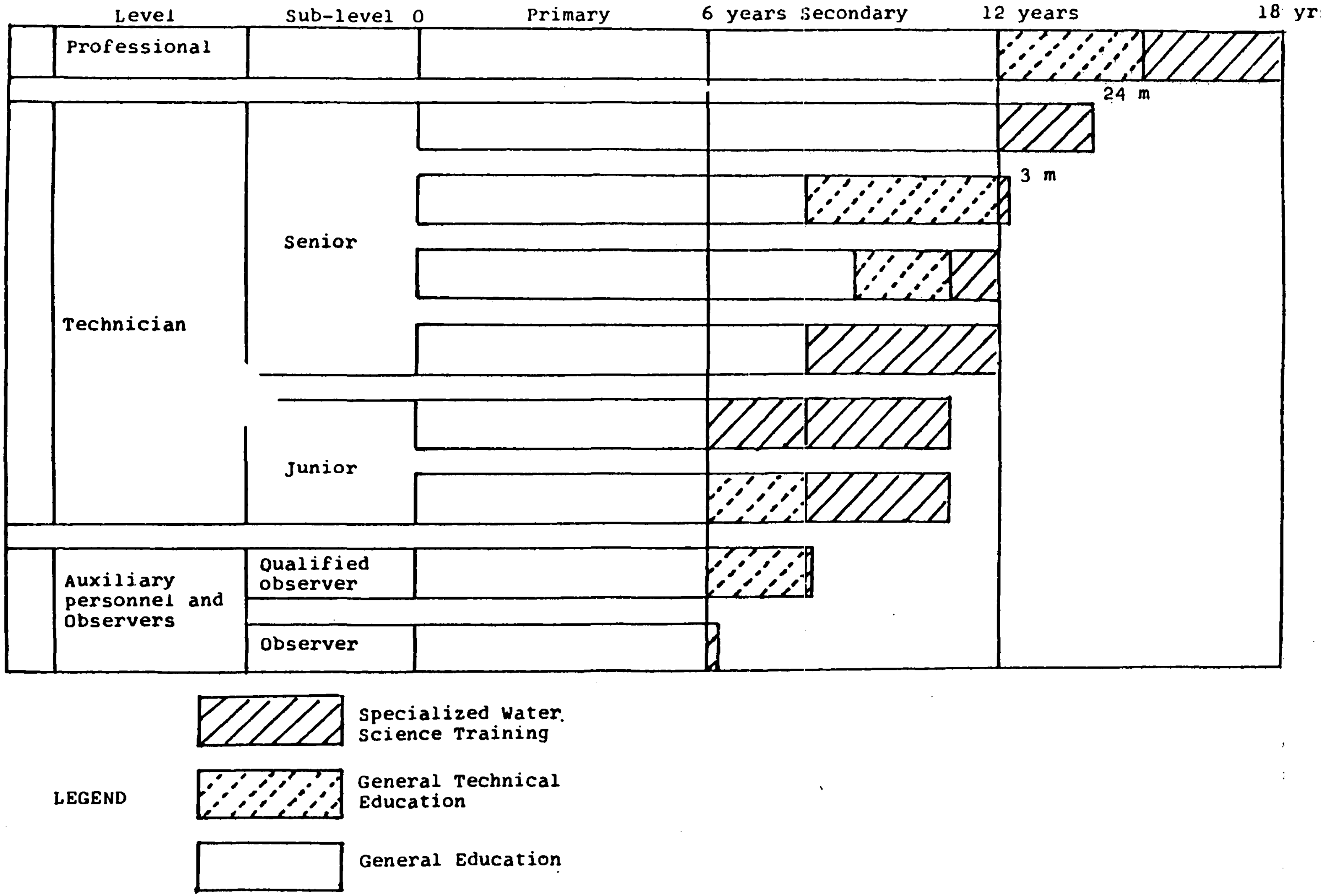

Figure 6.1 - SCHEME OF POSSIBLE EDUCATION SYSTEMS

6.2 Existing manpower and future needs

6.2.1 Manpower needs

Since the beginning of the 1960s, water-resource manpower surveys have been executed by a large number of countries and international and regional organizations, with or without expatriate assistance, in order to give the corresponding governments an idea of the personnel needed and of the qualifications required.

An evaluation of the data available to Unesco shows that the surveys considered have not been carried out as part of a concerted action but on an ad hoc basis. None is comparable with another, whether in scientific approach or in terms of definition, purpose and scope. Thus, the figures obtained give only a very limited impression in a number of countries or cases and are not suitable for use on a global scale. However, on the basis of the surveys and studies available to Unesco, Table 6.1 has been prepared. It illustrates very roughly the demand for professionals and technicians in the field of water resources in terms of the country's population. This table presents what amount to suggested reference levels for manpower. Similarly, WMO has developed guidelines for the determination of manpower requirements for hydrometrical and meteorological stations as shown in Table 6.2.

TABLE 6.1 - REQUIREMENTS FOR PROFESSIONALS AND TECHNICIANS IN THE WATER-RESOURCE FIELD

Natural and economic characteristics of the country	Professionals per million inhabitants	Technicians per million inhabitants
Low economic development; simple hydrological regime; no major problems in water use	5	30
Average conditions	15	80
High economic development; complicated hydrological regime; great problems in water use; multiple use of water	40	200

TABLE 6.2 - MANPOWER REQUIREMENTS FOR COLLECTION, PROCESSING AND ANALYSIS OF SURFACE WATER DATA

Item	Number of staff per 100 stations			
	Professionals	Technicians Senior	Technicians Junior	Observers
I Hydrometric stations				
- field operations and maintenance	1	5	5	100
- data processing, analysis and interpretation	2	3	3	-
- supervision	0.5	-	-	-
Sub-total	3.5	8	8	100
II Rainfall and evaporation stations				
- field operations and maintenance	0.5	2	2	100
- data processing, analysis and interpretation	1	2	2	-
- supervision	0.25	-	-	-
Sub-total	1.75	4	4	100

Notes:

1) Many observers work part time or on a voluntary basis.

2) The same field staff often performs the tasks included in items I and II.

3) Topographical and hydrographical characteristics and ease of access condition manpower needs in field and maintenance operations. Therefore, the figures shown will have to be adjusted in each case.

4) It is convenient for each country to carry out the evaluation on the basis of this table, taking into account the present and recommended operating conditions of its hydrometric, precipitation and evaporation stations. It will be possible to determine the future manpower needs by means of the subsequent table comparison by observing the expected growth percentages during a given period.

5) More details on staffing levels are given in Table 3.1.

In most countries throughout the world, and also in the international organizations, a great deal of information is available on existing manpower and forecasts of future needs. Although these data are not completely reliable, they can often be used to estimate at least the educational needs.

6.2.2 Evaluation of manpower status and future needs

The evaluation is carried out separately for the main fields of WRA, namely:

- institutional framework;
- data requirements for water-resource planning;
- data collection, processing and retrieval;
- areal assessment of water balance components;
- research and development.

The manpower problems which exist or are likely to occur in the above-mentioned fields should be indicated. Where a problem occurs which falls under any of the aforementioned headings, the "main field" should be broken down according to the section in the respective chapter of this handbook. There could be, for instance, the absence of trained personnel, lack of interest in the jobs offered or insufficient funds to employ personnel. In the case of the absence of trained personnel the reasons should be explored under sub-chapters 6.3 and 6.4. The evaluation should not only cover the quantity aspect but also the quality aspect. The human factor in training and in working conditions should be considered, however difficult it may be to quantify. Another aspect that may be evaluated, therefore, is the working and related social conditions of the different categories of personnel. For instance, does work in the field pose problems, or are there sufficient career possibilities to make water-resource assessment work attractive?

6.3 Formal education

In many countries there is a quantitative and/or qualitative shortage of educational facilities at all levels and in the majority of countries there are serious gaps at least at one level. A summary of the educational facilities directly or indirectly related to WRA should be prepared by the evaluator using tables similar to Table 6.3.

TABLE 6.3 - EDUCATION AND TRAINING IN WATER RESOURCES AND RELATED AREAS

COURSE	No. OF SCHOOLS REGULAR	No. OF SCHOOLS OCCASIONAL	DURATION (MONTHS)	PREREQUISITE EDUCATION	AVAILABLE INSIDE THE COUNTRY	AVAILABLE OUTSIDE THE COUNTRY	AVERAGE ANNUAL ENROLMENT	REMARKS	EMPAHSIS OF INDEX ARID SED.	EMPAHSIS OF INDEX ARID N.SED.	EMPAHSIS OF INDEX HUMID SED.	EMPAHSIS OF INDEX HUMID N.SED.
Meteorological observer												
Hydrological observer												
Hydrogeological observer												
Meteorological technician												
Hydrological technician												
Hydrogeological technician												
Surveyor (technician level)												
Pedological technician												
Geological technician												
Computer technician												
Meteorologist												
Hydrologist												
Hydrogeologist												
Hydraulician												
Surveyor												
Pedologist												
Geographer												
Engineer Bachelor's Degree Master's Degree Doctorate												
Systems analyst												
Mathematician												
Statistician												
Computer scientist												
Telecommunication technician												

Note: Examples of information to be included in this table, including proposals as to the emphasis levels, are presented in Appendix X.

The following formal educational and training levels can be distinguished:

(a) Primary and secondary general education - important as a preparation for further training.

(b) Junior technician education - usually undertaken within general technical education institutions.

(c) Senior technician education - generally undertaken within public works, civil engineering and agricultural schools and other educational institutions.

(d) University education - normally takes place as a specialization within civil, agricultural or mining engineering or other fields.

6.3.1 Definition of needs

The formal national educational structure should supply sufficient school and university graduates of the right background to cover the manpower needs of the different services and bodies with water-resource assessment tasks. In a stable situation, the number of yearly graduates from any school should represent approximately 15% of the number of corresponding staff. This percentage would normally supply the additional manpower requirements for normal moderate development of activities and replacement of personnel resulting from promotions, changes in career orientation, retirement or death. The required percentage might vary according to local circumstances such as changes in development rates, immigration and emigration conditions and administrative policies.

In the case of relatively small countries, it may be impractical to establish special courses for each required specialization. In that case the personnel may be trained abroad and the needs at national level should then be defined so as to provide the basic training up to a level that allows acceptance by foreign institutions.

6.3.2 Description of educational system

In most countries, the Ministry of Education, or equivalent, holds all the necessary information on the formal education system. Nevertheless, in some cases, it may be found that there are formal educational facilities under other ministries such as the Ministry of Agriculture. Any private institutions should also be described.

The description should be divided into general formal education and specialized formal education.

General formal education covers primary schooling, secondary schooling and university training. For each type of schooling the number of graduates, entry requirements and possible specializations should be given. These statistics are normally readily available.

Specialized education includes the training of personnel to be employed more or less directly for water-resource assessment activities. This specialized education should be described in more detail. For instance, if hydrologists are normally recruited from among civil engineering graduates, the civil engineering curriculum should be described in such detail as to facilitate an evaluation of appropriateness for water-resource assessment. Particular care should be exercised in the description of the education and training facilities for senior technicians as a large proportion of problems may arise in this field. Specialized formal water-resource assessment education for higher technicians exists only in a small number of countries. In most cases these specialists are recruited from among graduates of institutions dealing with such fields as public works engineering and irrigation or rural development engineering.

Important descriptive items are entry requirements, curricula, numbers of students over the last five years, capacity of the institution to increase the number of students, profile of the lecturers, ratio of hours of practical work versus classroom education, administrative aspects such as availability of fellowships, job opportunities and the kind of job the respective graduates are going into and the eventual social profile of entrants in this kind of education.

In some countries special technical schools for some aspects of water-resource assessment and development activities exist (e.g. groundwater borehole drilling schools). These should be described in detail. If relevant, regional training schools, such as the Regional Agrohydrometeorological Training School in Niamey, Niger, should be described. If formal education abroad is a normal practice, it should also be described.

6.3.3 Adequacy criteria and evaluation

As mentioned in 6.3.1, under stationary conditions the number of yearly graduates should represent roughly 15% of corresponding staff. If a considerable increase in manpower is foreseen, an additional growth percentage should be added to the 15%. Evaluation of the educational systems should start from the results of the evaluation of the manpower situation and in particular from the identified problems in that field.

If the educational facilities exist but the required numbers are still not produced, the reasons may be the lack of interest in this kind of study or an inadequate number of people with the required prerequisite schooling. In the latter case the prerequisite schooling system should be evaluated.

Quality aspects should be taken into account continuously. These aspects may have far-reaching consequences. For instance, it may be that a lack of engineers and scientists may be the result of poor teaching of scientific subjects at the primary or secondary school level.

Criteria which are relevant to the situation of the country concerned should be used. The task of the educational system is to produce personnel that can and will execute the necessary work in the particular environment of the given country and not the production of manpower according to one or another more or less international standard.

6.4 In-service training and other training activities

The following levels can be distinguished:

(a) Junior technician level - In-service training is most appropriate and practical at this level. In-service training means all training organized by the service or ministry in which the trainee is working. A problem may be that the supervisors are not trained to teach. Therefore the first step may be to provide pedagogical training for supervisors.

(b) Senior technician level - Even for countries which now have middle level formal education institutes, post-school training is particularly needed for those appointed to supervisory posts when formal education and/or in-service training has not yet been established.

(c) Post-university level - In general, post-university training is available and, in most instances, it is of a high level. This type of training lends itself greatly to international participation and, in fact, a large number of such courses accept non-nationals.

6.4.1 Definition of needs

In-service training and other post-school or post-university training may be needed to:

(a) adapt the general knowledge acquired at school to the specific requirements of the job to be done.

(b) acquire new knowledge as it becomes available or as the equipment, circumstances, or job requirements change;

(c) keep the quality of personnel at the required level.

These three kinds of post-formal training are necessary at all levels of hydrological personnel.

6.4.2 Description of existing situation

The situation has to be described level by level.

6.4.2.1 The junior technician level

The description has to refer to different relevant questions. What is the level of education of the recruited personnel and how are they trained initially to execute their duties? Is there an organized training effort by the ministry or service or are they trained on the job by their immediate supervisors? Is written material available to explain their tasks?

If, for instance, new instruments are introduced, how are observers trained to handle them? Does an awareness of the training needs of junior technicians and observers exist at the higher levels in the hierarchy?

6.4.2.2 Senior technicians and engineers

In principle, the same questions as for the junior technician level apply but at a senior level. In many countries this level may not exist and, if it does, frequently no special training activities take place at national level. If this is the case, it should be mentioned. Regional and other international training activities which have taken place in the recent past should be mentioned.

A most important aspect to be mentioned is the attitude towards continuous training of this category of personnel by the interested persons themselves and by their supervisors.

6.4.2.3 Post-university level

Engineers and scientists are expected to organize their training activities themselves. In the description of training activities for this level, organized national, regional and international courses followed by specialists from the country should be described as well as non-organized contacts with colleagues through professional and international associations.

6.4.3 Adequacy criteria and evaluation

In-service training activities have both a technical and social function and are of the greatest importance for keeping the work force competent and aware of their social and economic role. The evaluator will be required to apply his best judgment in indicating the extent to which in-service training contributes to the basic WRA programme.

Information provided to decision-makers, planners and the public concerning the problems of rational water use, management and control can also be considered as part of WRA. Some countries have a certain experience in this activity including special courses in schools, brochures, films and video-cassettes. The evaluator may wish to include information on these when reviewing WRA activities.

References to Chapter 6

Unesco (1974) The Teaching of Hydrology, Technical Papers in Hydrology No. 13, Paris.

Unesco (1983) Curricula and Syllabi in Hydrology, Technical Papers in Hydrology, No. 22, Paris.

7. RESEARCH AND DEVELOPMENT

7.1 Introduction

7.1.1 General

Research and development (R and D) is important for all basic WRA activities. Here R and D implies a careful, critical search to improve or adapt a methodology, techniques or instruments to improve one or more national water-resource activities whether this involves the discovery of new facts or not. This definition gives emphasis to applied research, but basic research is not to be forgotten as it may be applied and lead to practical results quite apart from leading to a general improvement of the understanding of natural phenomena. Indications on a number of agencies carrying out R and D in areas related to water can be found in Unesco (1974) and USGS (1979).

In the evaluation of R and D activities, care should be taken to consider not only activities within research establishments but also groups and individuals in government departments and services carrying out research and development activities.

The following characteristics of water resources are relevant when analysing research and development in this field:

- water-resource development has generally a multi-disciplinary character, requiring close collaboration between various development sectors (e.g. water supply, irrigation, animal husbandry, environment);
- research needs are very different from country to country and are mainly governed by climate, geography and land use;
- exploration and exploitation of water resources often requires sophisticated technology, especially with regard to groundwater;
- investment in water-resource development projects in developing countries often requires a large component of hard currency funds.

7.1.2 Technical areas of R and D

The following list of R and D themes, although not exhaustive, could be considered to include those most frequently relevant to basic WRA programmes:

- development of efficient equipment and techniques of measurement of water cycle elements and of physiographic characteristics (including remote sensing measurement techniques);
- design of networks for water cycle elements and of surveys for physiographic characteristics and estimation of errors of interpolation;

- analysis of space-time relationships between water cycle elements, meteorological and physiographic factors and related model building for space-time interpolation of water balance elements including techniques of interpolation of water cycle network data;

- water quality characterization and modelling;

- statistical characteristics of time series of water cycle data and relationships between these characteristics and physiographic characteristics and related techniques of time series synthesis.

The following themes generally lie beyond the range of basic WRA itself. Nevertheless, they are mentioned because of their connection with the specific topics of basic WRA in R and D projects:

- analysis of effects of man's activity on water cycle elements and techniques of forecasting changes in the regime of the water cycle elements, including changes in the statistics of the corresponding time series;

- techniques of quantity and quality conservation of water and of improved use of water included in various elements of the water cycle (e.g. reduction of specific use of water and pollution in various industries, use of brackish water for irrigation of certain crops, use of warm and/or eutrophicated water in fish farms);

- techniques for increasing the quantity of water in certain water cycle elements by using the water included in other elements (e.g. groundwater recharge, retention of flood water, evaporation reduction, increased infiltration in soils, increased condensation of air moisture);

- techniques for more efficient improvement of water quality and for the use of residual matter resulting from treatment processes;

- techniques for improved water extraction from the ground, improved water transportation and more efficient hydroelectric and pumping plants.

7.2 Science policy structure, research institutions and in-service research

Most countries have a clearly formulated national science and technology policy (see for example Unesco, 1974a). These policies vary greatly, going from "laissez-faire" to full co-ordination of R and D by a central body with the power to determine the funding of research on the basis of the relevance of research to national development objectives.

7.2.1 Description of needs

The R and D in the basic WRA field varies greatly from one country to another. However, it can be stated that the establishment of water-resource institutes is an effective way of strengthening the structure in the field of water-resource assessment in any country (Unesco, 1971).

Because of the interdisciplinary character of water-resource assessment, the science and technology policy structure in a country should provide a framework for co-operation and co-ordination of different R and D activities. In this respect too, the existence and working procedures of pertinent national committees (for instance committees for the International Hydrological Programme) are of importance.

7.2.2 Description of existing situations

Although water is given priority in many development plans, in most cases it is not easily identified when studying the science policy structure of a country because in most countries R and D relevant for the WRA programmes may be carried out in a large variety of institutions. Information should be given in a table such as Table 7.1 concerning research and development activities which are or will be carried out in the country, on the basis of the relevant science policy and the existing facilities and programmes. An example showing how to complete such a table is presented in Appendix XI.

7.2.3 Evaluation

The evaluation of the effectiveness of the science policy structure and research institutions for national WRA therefore requires that an inventory of R and D being carried out in the country be obtained, including the extent of co-ordination of research work and, from identified deficiencies in the overall water-resource assessment results (Chapters 2 to 5), those deficiencies due to an absence or an inappropriateness of the R and D structure be singled out. When these have been analysed the probable causes should be described and possible remedies proposed.

7.3 Consultancy services

The expression "consultancy services" covers all R and D activities and studies related to water-resource assessment which are contracted to national or foreign bodies. This also includes studies carried out by or through bilateral or multilateral technical assistance institutions.

Reference is made here only to consultancy services which relate to R and D programmes and not to those provided for other purposes.

TABLE 7.1 - PROGRAMMES OF R AND D INSTITUTIONS

INSTITUTION	SUBJECTS	STATUS		BUDGET ALLOCATION	DURATION
		IN PROGRESS	PLANNED		
First institute	Subject 1				
	Subject 2				
Second institute	Subject n				
	Subject n+1				
	Subject n+2				

TABLE 7.1 - PROGRAMMES OF R AND D INSTITUTIONS (contd.)

INSTITUTION	SUBJECTS	STATUS IN PRO-GRESS	PLANNED	BUDGET ALLOCATION	DURATION
Third institute	Subject x				

Notes: 1) This form can be used to make an inventory of the relevant projects which have been carried out in the country.

2) The table's format can be modified in order to classify the projects according to topics instead of institutions.

3) If appropriate, the column "Budget Allocation" can be divided into investment, operation, maintenance and other.

4) An example showing how to complete this table is presented in Appendix XI.

7.3.1 Determination of needs

The need for consultancies can be estimated simply as the total of planned necessary activities minus the capacity(ies) of the institute(s). The total planned activities have to be determined on the basis of information collected as shown in Chapters 3 to 6.

The frequency of contracting and the size of the contract depend on the existence or absence of suitable contractors, on the existence or absence of other possible ways of obtaining outside knowledge and, of course, they depend very much on the political-economical framework of a certain country.

7.3.2 Description of existing situation

The capacity of national consulting firms can best be estimated from a description of past accomplishments, related to past and current staff and equipment availability.

The capacity of foreign consulting firms is practically unlimited and need not be described. It is, however, necessary to describe the amount and nature of past and current foreign consultancies including those executed under technical assistance agreements.

7.3.3 Evaluation

Four aspects have to be evaluated. The first is the desirable versus actual capacity of the contracting institution to prepare and follow-up consultancy contracts. It requires a scientific and administrative competence within the contracting institution of comparable level with that of the consulting firm. Comparable here means that the work of the consulting firm must be fully understood at the general supervisory level.

The second aspect is the desirable versus actual capacity of potential contractors within the country. In the case where the law prohibits contracting, no evaluation is possible. If contracting is not restricted it may be expected that the capacity of the consulting firms is satisfactory; otherwise they would be eliminated by free market competition. This situation, however, is not the case in the majority of countries. The most obvious limitation is the requirement that priority must be given to national consulting firms. In this last case the evaluation of the capacity of national contractors is of importance.

The third aspect is the desirable versus actual ratio of national to international contracting. In general, it may be said that in the case of comparable technical competence preference should be given to national contractors as it is more likely that they will have a better knowledge of the environment and socio-economic conditions. It may thus be expected that the development of national consultancy capacity improves national water-resource assessment activities.

The fourth aspect is the desirable versus actual ratio of direct contracting to contracting through foreign technical assistance. In general, the contracting institution has more influence over the work to be performed in the first case.

Of these four aspects the first - that is the capacity of the contracting institution - is the most important one.

In the evaluation of consultancy services systems for research and studies in the field of water-resource assessment, it is important that the existing socio-political-economic situation and development objectives of the country be fully taken into account.

7.4 Exchange of information and documentation

The collection, processing, storage and retrieval of data necessary for water-resource assessment have been dealt with in Chapters 3 and 5. In this subchapter information is meant to be scientific and technical knowledge and experience concerning methodologies, methods, techniques and equipment for water-resource assessment, or in other words the results of studies and research. Documentation in this respect implies cataloguing, storage and distribution of such information by various means (paper, filing, magnetic tape).

Information obtained personally through education is dealt with in Chapter 6.

The need for information in the field of water-resource assessment research is basically not very different from that in water-resource research in general. A general water-resource information system will, therefore, be appropriate in practically all cases.

7.4.1 Determination of needs

The least information that should be accessible to all water-resource specialists is national and international up-to-date literature in the form of books and specialized magazines. This requirement is not met in the majority of countries. The result is invariably a gradual diminishing of self-confidence of the specialists and consequently a high recourse to foreign consultancy.

The most sophisticated information system is a computerized national information centre that has on-line connection with foreign computerized information centres.

The most productive information will, in most cases, be study and research results concerning cases in the country itself, whether this research was done by national or foreign bodies. These reports should be easily retrievable and consultable. The second set of information needed is foreign information concerning similar natural phenomena or situations.

The size and sophistication of the information system should be in relation to the needs for information, the capacity of the information user to make use of the information provided and the delays that are acceptable between requests for information and production of it.

7.4.2 Description of existing situation

A comprehensive list of institutions and bodies with or including a documentation or information service in water resources should be made. In addition, a list of national information producers should be established.

The interrelations between information users and information producers, that is the flow of information, also needs to be described. It is also required to describe how a national specialist will go about obtaining the information needed, as well as what happens in general to study reports after they have been produced.

The above concerns information produced and used nationally. As regards international knowledge, the availability and accessibility of foreign information in the country itself should be described together with the possibility of obtaining foreign literature from outside the country.

7.4.3 Evaluation

The key person in the information cycle is the user. It is, therefore, necessary to first evaluate the willingness and capacity of the user to apply information. If this capacity is very low, due for instance to limited specialized manpower, then it is still necessary for the results of studies made in or around the country to be available and accessible to consultancy firms and technical assistance experts. This accessibility should then be evaluated. In cases where motivation and capacity to apply information exists, the evaluation is to be based on the difficulties encountered in obtaining useful information.

As information users are frequently information producers, the willingness of information producers to assist institution libraries or national documentation centres by supplying information should also be evaluated.

References to Chapter 7

Unesco (1971), Outline of a Methodology for Determining Institutional Needs of Developing Countries in the Field of Science and Technology, Document NS/Ron 211, rev. 1, Paris.

Unesco (1974), Environmental Research and Development Related to the Hydrosphere, Document SC/74/CONF. 647/6, Paris.

Unesco (1974a), National Science Policies in Africa, Science Policy Studies and Documents Series No. 31, Paris.

USGS (1979), Worldwide Directory of National Earth Science Agencies, Arlington. VA.

8. PRACTICE OF WRA EVALUATION

8.1 Overall approach

8.1.1 Portrait of the evaluator

The evaluator can be an individual, a technical group, a public institution or a consultant firm, with a deep knowledge of the water-resource inventory concerned and sufficient information on long-term WRP so as to be able to evaluate the needs of basic data.

8.1.2 Activities

The evaluator will have to complete the work described in the previous chapters, which will enable him to have a comprehensive description of the basic WRA activities and of the problems encountered in long-term WRP because of inadequate basic WRA. He will then need to evaluate the actual activities using indexes and reference levels which should be developed specifically for the country or region in question. These should take into account :

- the hydro-climatological characteristics of the country;
- the socio-economic characteristics of the country;
- appropriate recommended practices, including the suggested emphasis and reference levels contained in the appendices to this handbook;
- information available to him concerning indexes and reference levels used in countries considered to have satisfactory basic WRA programmes.

8.1.3 Flexibility

The evaluation process requires sound judgment and extensive experience, for the comparisons mentioned in 8.1.2. should not be regarded as an exclusive basis, it being necessary to use flexible procedures in accordance with local conditions. To illustrate this, assume for example a country in which the density of the network is sufficiently high to enable interpolation of hydrological data at any point of the area with high accuracy, but which has unsatisfactory surveys of physiographic characteristics. As the areal assessment of the surface water resources is still possible, it would not be rational to declare that the basic WRA programme is inadequate from the viewpoint of surface water resources.

The evaluator should be very careful concerning the significance and causative relationships of different components, trying to uncover the main causes of inadequacy. This may be related to lack of proper technological means, lack of funds, low level of skills, education and training or a combination of the above. A comprehensive analysis of the situation and in particular of the historical data will make it possible to find the major causes of the deficiencies.

8.1.4 Final report and recommendations

In the evaluation and recommendation stage the evaluator will have to make best use of the background data, of his general knowledge of the area and of his own personal judgment. The extensive interaction he has had with organizations and personnel involved in the basic WRA programme during the collection of background information should also provide input for his evaluation and related recommendations. In view of the above, the evaluation guidelines that follow should be considered tentative and used in a flexible manner.

8.2 Evaluation guidelines

8.2.1 Institutional arrangements

Figure 1.2 (f) overlain on river basin boundaries and Table 2.1 should be used for the evaluation in conjunction with completed Table 5.2. Specific points to be considered might include:

- difficulties in obtaining flows at jurisdictional boundaries and their effect on long-term WRP;
- activity duplication and efficiency reduction in utilization of measurement and inspection crews;
- difficulties resulting from inconsistencies in standards and techniques.

The results of the above analysis should be used to evaluate if there is a relationship between the type of institutional arrangement and the significance of the above-mentioned problems.

Recommendations should refer to possible reduction of the above deficiencies through interjurisdictional co-ordination and inter- and intra-jurisdictional compacts or boards.

8.2.2 International co-operation programmes

The pertinent references to Chapter 2 should be used to ascertain the usefulness of guides and handbooks on basic WRA prepared by international organizations in standardizing and streamlining basic WRA in the given country.

Completed Table 2.2 should be used to provide measure of the participation of the country in international projects.

The impact of technical co-operation programmes on national WRA activities should be assessed by applying the pertinent tables in Chapters 3 to 7 to the current situation, noting in each case the extent to which the activities are dependent on external assistance. By doing so, the evaluator will establish the part of basic WRA which is dependent on international co-operation.

Recommendations should concentrate on possible improvement of the contribution of international co-operation programmes to basic WRA activities. With the help of the above information the evaluator should identify the very successful projects which should be emulated and the very unsuccessful projects. Where examples of successful international co-operation projects are not available for the given country, the evaluator could use examples from other countries on which he should base his recommendations. A second iteration in making recommendations on international aid should be considered after all required improvements in basic WRA activities have been identified.

8.2.3 Data networks and surveys

Completed Table 3.1 should be used in conjunction with Appendix IV to ascertain whether or not the hydrological and hydrogeological networks have characteristics below or above the corresponding reference levels. In general, the evaluation of adequacy related to network characteristics should be made in general simply through this comparison, taking into account the conditions which prevail in each country.

Completed Table 3.2 and Appendix V should be used to evaluate the proportion of water-resource projects and water uses for which data are collected. The data collection system for this purpose should be considered adequate if all major projects and a representative sample of the other projects are gauged.

Completed Table 3.3 and Appendix VI should be used to evaluate the proportion of each region for which physiographic surveys of various types are available. The proportions should be considered adequate if they are not below the level required for estimating information for long-term WRP.

Completed Table 3.4 and Appendix VII should be used to evaluate the proportion of data collected which are properly stored and published. These proportions should be considered adequate only if they approach 100%. The same table and appendix should be used to evaluate the problems, if any, of obtaining data by users. The evaluation of these problems should be done in consultation with the data users and in particular the users for long-term WRP

Recommendations in this area should simply indicate the technical and financial means, including international aid, and the technical and professional staff required to upgrade the characteristics of the networks at or above the corresponding activity levels to values that are considered adequate.

8.2.4 Areal assessment of water balance components

Completed Table 4.1 and Appendix VIII should be used to evaluate the adequacy of techniques for areal assessment of water balance components. The evaluator should consider the latter adequate if the accuracy of the available techniques satisfies the requirements of long-term WRP.

Recommendations should be made on the basis of an analysis of the main causes of inaccuracy. These may relate to network density, lack of or inaccurate physiographic characteristics, or poor models (techniques). When the evaluator is in great doubt about the major causes of the inaccuracies, he could recommend a study for ascertaining them. However, it is to be expected that the evaluator will be able, by using his experience and judgment, to identify the major causes. On this basis he could either revise his previous recommendations regarding the network characteristics and physiographic data surveys or recommend the testing of better techniques (models), or both.

8.2.5 Data requirements for long-term water-resource planning

Table 5.1 and Appendix IX should be used to provide information on the type and format of data required, and the acceptable accuracy. The evaluator should use this information, as inputs to an evaluation of the network performance, with respect to providing the measurement (8.2.3) and interpolation (8.2.4) of water balance data for WRP. He should then attempt to obtain a quantitative appraisal of his initial evaluation of the adequacy of the basis WRA programme (see Section 5.3).

8.2.6 Education and training

The completed Table 6.4 and Appendix X should be used to estimate, on the basis of the analysis described in Chapter 6, whether or not the existing training and education programmes and corresponding enrollment rates can satisfy the requirements for adequate institutional framework , improved networks and surveys and related activities, better interpolation techniques and related research and development. Recommendations should be made with respect to adding to or improving existing programmes or making use of international co-operation in this field to train personnel abroad when this is not possible within the country.

8.2.7 Research and development

The results of the previous evaluation steps, and the analysis described in Chapter 7 (see Section 7.2) and completed Table 7.1 should be used to evaluate the adequacy of research and development for basic WRA purposes. Table 7.1 provides data on what research and development activities are or will take place in the country on the basis of the corresponding science policy and existing facilities and programmes.

It should be noted that in the area of research and development more than in other areas the evaluation process is complex and recommendations for improvement require the consideration of general and long-term conditions and may need several iterations.

8.2.8 Overall evaluation

After consideration of all steps indicated in sections 8.2.1 to 8.2.7 above, the evaluator will have a set of qualitative and quantitative results describing the state of the different activities of the WRA programme of the given country.

He will be able to compare these results with other activity or reference levels available to him, due to his familiarity with WRA programmes, or obtained by other evaluators in other countries and regions.

No attempt has been made in this handbook to develop a general formula leading to the definition of a single index for an overall evaluation of all activities concerned. The results obtained from the analysis of the different activities will have a different importance varying in space and time and it will be up to the evaluator to consider this question as it may be applicable to the specific case with which he deals.

The evaluation process requires judgement and experience and although the different indices collected in the above mentioned steps will always provide valuable information, they are unlikely to serve as the only basis for the final evaluation. Experience with the use of the methodology presented in this handbook has already shown great variety in the manner and extent to which it is applied in different countries and such variety is expected to be seen also in its further use.

APPENDIX I

RESOLUTION I OF THE UNITED NATIONS WATER CONFERENCE

"ASSESSMENT OF WATER RESOURCES"

The United Nations Water Conference in its Resolution I "Assessment of Water Resources"

Recognizing that for the plans of action adopted by the Conference for the intensification and improvement of water use and development in agriculture and for providing safe drinking water and sanitation for all human settlements by 1990, a proper assessment is necessary of water resources in all countries of the world, and in particular in developing countries,

Considering that this assessment can be achieved only if all countries strengthen and co-ordinate arrangements for the collection of data in accordance with the recommendations of the Conference,

Resolves that:

(a) All efforts should be undertaken at the national level to increase substantially financial resources for activities related to water-resource assessment and to strengthen related institutions and operational services as necessary and appropriate at the national and regional levels;

(b) Training programmes and facilities for meteorologists, hydrologists and hydrogeologists should be established or strengthened;

(c) National scientific infrastructure for water-assessment activities be strengthened or established, particularly in developing countries;

(d) International co-operation aimed at the strengthening of water-resources assessment, particularly within the International Hydrological Programme (IHP) of Unesco and Operational Hydrological Programme (OHP) of the World Meteorological Organization (WMO) be keyed to the targets set by the United Nations Water Conference and appropriately supported by national and international governmental and non-governmental institutions.

APPENDIX II

CONTRIBUTION OF INTERNATIONAL ORGANIZATIONS TO BASIC WRA

1. WORLDWIDE ORGANIZATIONS

1.1 Unesco

The Unesco document 20 C/5, "Draft Programme and Budget for 1979-1980", under "Assessment of water resources", mentions:

- methods of computation of water balances and their elements including groundwater;
- evaluation of water balances at global, continental, national, regional and basin level;
- the computation of the elements of the hydrological regime for water-resources planning and management;
- the determination of fluctuations and long-term trends in the hydrological regime.

This document further states:

"Methodology will be developed for the assessment of water resources for the elaboration in each country of a rational water policy based on objective scientific data and suited both to the natural features of the country and its economic and social development needs".

Unesco's activities in the field of basic WRA currently take place mainly in the framework of the International Hydrological Programme (IHP) (Unesco, 1977).

1.2 WMO

Practically all the activities of WMO in the field of hydrology and water resources and part of its activities in meteorology pertain to basic WRA. Indeed WMO has specifically included activities in the field of hydrology and water resources in its basic document, the Convention of WMO, as follows:

"The purposes of the Organization shall be:

(a) To facilitate world-wide co-operation in the establishment of networks of stations for the making of meteorological observations as well as hydrological and other geophysical observations related to meteorology, ...;

(d) To further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities;

(e) To promote activities in operational hydrology and further close co-peration between Meteorological and Hydrological Services;

(f) To encourage research and training in meteorology and, as appropriate, in related fields and to assist in co-ordinating the international aspects of such research and training."

The scope of the WMO "Operational Hydrology Programme" within the context of the WMO Convention is defined as:

"(a) Measurement of basic hydrological elements from networks of meteorological and hydrological stations; collection, transmission, processing, storage, retrieval and publication of basic hydrological data;

(b) Hydrological forecasting;

(c) Development and improvement of relevant methods, procedures and techniques in:

(i) Network design;

(ii) Specification of instruments;

(iii) Standardization of instruments and methods of observation;

(iv) Data transmission and processing;

(v) Supply of meteorological and hydrological data for design purposes;

(vi) Hydrological forecasting".

WMO also co-operates with Unesco in the framework of the IHP and with other international and national organizations concerned with WRA in various ways.

1.3 Other organizations of the UN system

These activities have been defined by the organizations themselves, namely within the United Nations Administrative Committee on Co-ordination (UN/ACC), and were presented to the ECOSOC Committee on Natural Resources (CNR) in November 1972 (Doc. E/C.7/38/Add.1). They are reproduced in Annex 1 to that document but can be summarized with respect to WRA as follows:

UN Headquarters: Economic and institutional aspects of water-resource development and use (water administration and law), exploration of groundwater resources and general water-resource surveys.

UN Regional Economic Commissions: In general, co-ordination of international water-resource activities in the region as they pertain to economic and social development.

FAO: In its central area of activities the Food and Agricultural Organization of the United Nations (FAO) is developing effective water-resource inventories within its sectoral responsibility for water as a basic resource for agriculture, forestry and fisheries.

WHO: Activities of the World Health Organization (WHO) include collection and assessment of data on environmental and sanitary conditions in rivers and other natural water resources used as sources of community water supply.

IAEA: The International Atomic Energy Agency (IAEA) is active in the collection of environmental isotope data and use of isotopes in WRA.

UNEP: Monitoring of inland waters to assess environmental impacts is an activity of the United Nations Environment Programme (UNEP) (within the Global Environmental Monitoring System (GEMS), see UNEP/WHO/Unesco/WMO, 1977).

It should be noted that the above-mentioned activities in WRA cover all facets of the assessment of requirements and needs for water supply: the UN Headquarters on a multi-purpose basis, and FAO and WHO on a sectoral basis.

Many projects supported by the United Nations Development Programme (UNDP) have had as primary or subsidiary purpose the assessment of the water resources of one or several countries. Most projects in which Unesco, WMO, WHO, FAO and other UN agencies act as technical executing agencies are financed by UNDP. Similarly, many projects financed by the International Bank for Reconstruction and Development (IBRD) have had WRA components.

Other non governmental international organizations such as the International Institute of Applied Systems Analysis (IIASA) have shown concern with water-resource problems and developed projects and studies in this field.

2. REGIONAL ORGANIZATIONS

Most regional multinational organizations with economic or other purposes have been involved to a great or lesser degree in WRA. Examples are the Organization for Economic Co-operation and Development (OECD), the European Economic Community (EEC), the Council for Mutual Economic Aid (CMEA), the Inter-State Committee on Drought Control in the Sahel (CILSS), the Organization of American States (OAS). The preoccupations of OECD in the water-resource field led, for example, to the development of an aid project for alleviating drought problems in the Sahel area. The EEC and CMEA have been active mainly in the fields of water quality and management. The CILSS has made extensive investigations on the availability of water resources in the countries of the Sahel area and on the management and development of water resources in this region. The OAS has sponsored several regional development projects, some of which are centred around water-resource projects, most of which include WRA.

In addition to the above-mentioned activity of multinational organizations, it is worth noting also the significance for WRA of agreements made between international organizations together with several donor countries and one or several recipient countries involving water-resource projects and developments. Such projects contain WRA components. Examples are the agreement between UNDP, the Organization of the Petroleum Exporting Countries (OPEC), EEC, France's Fonds d'assistance et coopération (FAC) as donors and the River Niger Commission as recipients, or the UNDP, US(AID), FAC, Belgium, the Netherlands as donors and the CILSS as recipient.

3. BILATERAL AGREEMENTS

Two types of bilateral agreements are of significance in water assessment. The first type is represented by comprehensive agreements on matters of common interest between neighbouring countries, which cover also water-resource matters. The second type consists of aid agreements between one donor and one recipient country on water-resource assessment and development or related projects.

Examples of the first type of agreement are the Canada-US Boundary Waters Treaty (1909), the Egypt-Sudan Nile Waters Agreement (1959) and the Senegal-Gambia, Senegambia Permanent Secretariat (1977). Examples of the second type of agreement are those between France and a number of countries in Africa for carrying out basic WRA through the Office de la recherche scientifique outre-mer (ORSTOM), between West Germany and various countries in the world such as Nepal and Bolivia for carrying out WRA and management studies through Gesellschaft für Technische Zusammenarbeit and between Canada and Columbia for hydrometeorological investigations through the Canadian International Development Agency (CIDA).

APPENDIX III

EXAMPLE OF IDENTIFICATION OF INSTITUTIONS AND TASKS INVOLVED IN A BASIC WRA

Main type of activity \ Jurisdiction	Federal Government				Government of Province A				Government of Province B			
	Institution	Tasks	Area covered	Task starting date	Institution	Tasks	Area covered	Task starting date	Institution	Tasks	Area covered	Task starting date
Meteorological	Meteorological Serv. of Air Transport Dept.	Collection of precipitation data Collection of air humidity data Collection of evapo. data	Whole country Whole country Whole country	1890 1910 1965	Agrometeorological Office of the Ministry of Agriculture Meteorological Office of the Min. of Environm.	Collection of precipitation data Processing of information on precip. Collection of evapotranspiration data Collection of soil moisture Collection of data on water quality of precipitation	Whole state Whole state North of parallel 12°N Ditto Whole state	1920 1950 1970 1975 1975	Agrometeorological Office of the Ministry of Agriculture	Collection of evapotranspiration data	North of parallel 12°N	1972
Hydrological	Hydrological Service of the Ministry of Public Works	Collection of level, flow & water quality data of surface water	Whole country	1925	Hydrological Service of the Ministry of Energy	Collection of level and flow data	South of parallel 12°N	1965	Hydrological Service of the Ministry of Urban Development	Collection of level, flow & water quality data	North of parallel 12°N	1965
Hydrogeological	Hydrogeological Division of Geological Survey	Collection of level, hydraulic characteristics and quality data of groundwater bodies	North of parallel 12°C	1935	Water Supply Division of the Ministry of Planning	Collection of levels and water quality data	South of parallel 12°C	1968	Hydrogeological Service of the Ministry of Mines	Collection of water level & hydraulic characteristics data of groundwater bodies	Mining district C	1975

APPENDIX IV

SUGGESTED EMPHASIS AND REFERENCE LEVELS FOR COLLECTION OF BASIC DATA

EVALUATION ELEMENTS	EMPHASIS* AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
Precipitation stations; non-recording (Number per 10^4 km^2)	H 6	H 6	M 20	M 40	H 6	H 6	M 20	M 40
Precipitation stations: recording (Number per 10^4 km^2)	H 1.5	H 1	H 2	H 2	H 1.5	H 1	H 2	H 2
Evaporation stations; non-recording (Number per 10^5 km^2)	H 3	H 3	M 2	M 2	H 3	H 3	M 3	M 2
Evaporation stations; recording (Number per 10^6 km^2)	L 1	L 1	L 0	L 0	L 1	L 1	L 0	L 0
Snow courses; conventional (Number per 10^4 km^2)	H 3	H 3	M 2	M 2	N.A.	N.A.	N.A.	N.A.
Stations measuring water quality of liquid and solid precipitation (Number per 100 precipitation and snow courses)	H 25	H 25	M 10	M 10	H 25	H 25	M 10	M 10
Meteorological satellite receiving stations (Number per 10^6 km^2)	H 1	H 1	H 1	H 1	H 1	H 1	M 1	M 1
Surface water level stations; non-recording (Number per 10^4 km^2)	H 0.6	H 1.2	H 12	H 24	H 1.2	H 2.4	H 12	H 24

* L = Low emphasis
M = Medium emphasis
H = High emphasis
N.A. = Not applicable

SUGGESTED EMPHASIS AND REFERENCE LEVELS FOR COLLECTION OF BASIC DATA (contd.)

EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
Surface water level stations; recording (Number per 10^4 km^2)	H 0.3	H 0.3	H 1	H 1	H 0.6	H 1	H 1	H 1
River discharge stations: (a) (Number per 10^4 km^2)	H 0.5	H 1	H 10	H 20	H 1	H 2	H 10	H 20
Sediment discharge stations (Number per 10^4 km^2)	H 0.3	H 0.2	M 3	M 2	H 0.7	H 0.4	M 5	M 3
Surface water temperature stations (Number per 10^4 km^2)	M 0.3	M 0.2	M 3	M 2	M 0.7	M 0.4	M 5	M 3
Water quality of surface water (Number per 10^4 km^2)	H 0.3	H 0.2	H 3	H 2	H 0.7	H 0.4	H 5	H 3
Groundwater level stations; non-recording (Number per 10^4 km^2)	H 5	H 2	M 2	M 0.5	H 5	H 2	M 2	M 0.5
Groundwater level stations; recording (Number per 10^5 km^2)	H 2	H 1	M 2	M 1	H 2	H 1	M 2	M 1
Groundwater stations measuring hydraulic characteristics (Number per 10^4 km^2)	H 5	H 2	M 2	M 0.5	H 5	H 2	M 2	M 0.5
Groundwater quality stations (Number per 10^5 km^2)	H 5	H 3	M 5	M 3	H 5	H 3	M 5	M 3

SUGGESTED EMPHASIS AND REFERENCE LEVELS FOR COLLECTION OF BASIC DATA (contd.)

EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
Repair and maintenance shops for meteorological equipment (Number per 200 precipitation stations)	H 2	H 2	H 1	H 1	H 2	H 2	H 1	H 1
Current meters (Number per 10 discharge stations)	H 2	H 2	H 1	H 1	H 2	H 2	H 1	H 1
Rating facilities for current meters (Number per 200 current meters)	H 2	H 2	H 1	H 1	H 2	H 2	H 1	H 1
Repair and maintenance shops for hydrological equipment (Number per 200 discharge stations)	H 2	H 2	H 1	H 1	H 2	H 2	H 1	H 1
Water sediment laboratories (Number per 100 sediment stations)	H 5	H 5	M 3	M 3	M 5	H 5	M 3	M 3
Water quality laboratories (Number per 100 water quality stations)	H 5	H 5	M 3	M 3	M 5	H 5	M 3	M 3
Well drilling sets (Number per 10^6 km^2)	H 20	H 10	M 10	M 2	H 20	H 10	M 10	M 2
Repair and maintenance shops for well drilling sets (Number per 10 well drilling sets)	H 1	H 1	M 1	M 1	H 1	H 1	M 1	M 1
Meteorological station observers (Number per precipitation station)	H 1	H 1	H 1	H 1	H 1	H 1	H 1	H 1
Water level observers (Number per water level stations)	H 1	H 1	H 1	H 1	H 1	H 1	H 1	H 1
Inspectors of meteorological stations (Number per 100 precipitation stations)	H 10	H 10	H 5	H 5	H 10	H 10	H 5	H 5

SUGGESTED EMPHASIS AND REFERENCE LEVELS FOR COLLECTION OF BASIC DATA (contd.)

EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS							
	TEMPERATE				TROPICAL			
	ARID		HUMID		ARID		HUMID	
	SED.	N.SED.	SED.	N.SED	SED.	N.SED	SED.	N.SED
Hydrological field teams (2-3 persons) (Number per 10 discharge stations)	H 2	H 2	H 1	H 1	H 2	H 2	H 1	H 1
Special survey teams surface water (3-4 persons) (Number per 10^5 km^2)	H 2	H 2	M 1	M 1	H 2	H 2	M 1	M 1
Special survey teams ground water (3-4 persons) (Number per 10^5 km^2)	H 4	H 2	M 3	M 1	H 6	H 3	M 4	M 2
Superstructure staff meteorology (Number per 100 precipitation stations)	H 3	H 3	H 3	H 3	H 3	H 3	H 3	H 3
Superstructure staff surface water (Number per 100 river discharge stations)	H 4	H 4	H 4	H 4	H 4	H 4	H 4	H 4
Superstructure staff groundwater (Number per 100 groundwater monitoring stations)	H 4	H 4	M 4	M 4	H 4	H 4	M 4	M 4

(a) These are either conventional or recording surface water level stations where streamflow measurements are made.

(b) Two or three of these repair shops may be combined into a dual or multipurpose one.

APPENDIX V

SUGGESTED EMPHASIS LEVELS FOR AVAILABILITY OF DATA ON WATER-RESOURCE PROJECTS

TYPE OF DATA ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Large water-resource projects	Percentage of storages surveyed	medium	high	medium	high
	Percentage of abstractions surveyed	medium	high	medium	high
	Percentage of diversions surveyed	high	high	high	high
	Percentage of returns of polluted water surveyed	high	high	high	high
Medium and small water-resource projects	Percentage of storages surveyed	medium	high	medium	high
	Percentage of abstractions surveyed	medium	high	medium	high
	Percentage of diversions surveyed	high	high	high	high
	Percentage of returns of polluted water surveyed	high	high	high	high

APPENDIX VI

SUGGESTED EMPHASIS LEVELS FOR PHYSIOGRAPHIC DATA

TYPE OF DATA ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Topographic	Percentage of area covered by 1:1 000 000 maps	high	high	high	high
	Percentage of area covered by 1:250 000 maps	medium	low	medium	low
	Percentage of area for which river network checked on ground or with special technique	high	low	high	low
Geological and geomorphological	Percentage of area covered by 1:1 000 000 maps	high	high	high	high
	Percentage of area covered by 1:250 000 maps	medium	low	medium	low
	Percentage of area for which piezometric levels available	high	high	high	high
	Percentage of area for which hydrogeochemical characteristics available	medium	high	low	low
	Percentage of area for which hydraulic parameters available	high	medium	low	low
Pedological	Percentage of area covered by 1:1 000 000 maps	high	medium	high	medium
	Percentage of area covered by 1:250 000 maps	medium	low	medium	low
	Percentage of area for which hydrogeochemical characteristics of soils can be estimated	high	high	medium	low

TYPE OF DATA ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Land-use Land-cover	Percentage of area covered by 1:1 000 000 maps	high	high	high	high
	Percentage of area covered by 1:250 000 maps	medium	low	medium	low
	Percentage of area covered by updated (biennially) maps	high	high	high	medium

APPENDIX VII

SUGGESTED EMPHASIS LEVELS FOR DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
DATA STORAGE AND CATALOGUING					
Water cycle data					
Meteorological and hydrological	Percentage stored as originals	medium	medium	medium	medium
	" " on microfilms	"	"	"	"
	" " in CCF	"	"	"	"
	" " in duplicate	high	high	high	high
	" lost or not stored	"	"	"	"
	" fully catalogued[1)]	"	"	"	"
	Time required to locate a specific datum	"	"	"	"
Hydrogeological	Percentage stored as originals	high	high	high	high
	" " on microfilms	medium	medium	medium	medium
	" " in CCF	"	"	"	"
	" " in duplicate	high	high	high	high
	" lost or not stored	"	"	"	"
	" fully catalogued[1)]	"	"	"	"
	Time required to locate a specific datum	"	"	"	"
Physiographic data					
Topographical	Percentage stored as originals	high	high	high	high
	" " on microfilms	medium	medium	medium	medium
	" " in CCF	"	"	"	"

SUGGESTED EMPHASIS LEVELS FOR DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Topographical (contd.)	Percentage or not stored	high	high	high	high
	" fully catalogued[1)]	"	"	"	"
	Time required to locate a specific datum	"	"	"	"
Geological and geomorphological	Percentage stored as originals	high	high	high	high
	" " on microfilms	medium	mediumn	medium	medium
	" " in CCF	"	"	"	"
	" lost or not stored	high	high	high	high
	" fully catalogued[1)]	"	"	"	"
	Time required to locate a specific datum	"	"	"	"
Pedological	Percentage stored as originals	high	high	high	high
	" " on microfilms	medium	medium	medium	medium
	" " in CCF	"	"	"	"
	" lost or not stored	high	high	high	high
	" fully catalogued[1)]	"	"	"	"
	Time required to locate a specific datum	"	"	"	"
Land-use/land-cover	Percentage stored as originals	high	high	high	high
	" " on microfilms	medium	medium	medium	medium
	" " in CCF	"	"	"	"

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Land-use/land-cover (contd.)	Percentage lost or not stored	high	high	high	high
	" fully catalogued[1]	"	"	"	"
	Time required to locate a specific datum	"	"	"	"
	Landsat imagery available (photo and CCT's)	medium	high	medium	high
CONVENTIONAL DATA BANKS					
Water cycle data					
Meteorological	Percentage of data included	high	high	high	high
	Lag between request and receipt of data	high	high	high	high
Hydrological	Percentage of data included	high	medium	high	medium
	Lag between request and receipt of data	"	"	"	"
Hydrogeological	Percentage of data included	"	"	"	"
	Lag between request and receipt of data	"	"	"	"
Physiographic data					
Topographical	Percentage of data included	medium	medium	medium	medium
	Lag between request and receipt of data	high	high	high	high
Pedological	Percentage of data included	medium	medium	medium	medium
	Lag between request and receipt of data	high	high	high	high
Geological and geomorphological	Percentage of data included	medium	high	medium	high
	Lag between request and receipt of data	"	"	"	"
Land-use/land-cover	Percentage of data included	medium	medium	medium	medium
	Lag between request and receipt of data	high	high	high	high

SUGGESTED EMPHASIS LEVELS FOR DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
COMPUTERIZED DATA BANKS[2)]					
<u>Water cycle data</u>					
Meteorological	Computer types, core memories and peripherals (list separately)	high	high	high	high
	Programmers (number)	"	"	"	"
	Average no. of years of education and experience	medium	medium	medium	medium
Hydrological	Computer types, core memories and peripherals (list separately)	high	high	high	high
	Programmers (number)	"	"	"	"
	Average no. of years of education and experience	medium	medium	medium	medium
Hydrogeological	Computer types, core memories and peripherals (list separately)	medium	high	medium	high
	Programmers (number)	"	"	"	"
	Average no. of years of education and experience	"	"	"	"
<u>Physiographic data</u>					
Topographical	Computer types, core memories and peripherals (list separately)	medium	medium	medium	medium
	Programmers (number)	"	"	"	"
	Average no. of years of education and experience	"	"	"	"
Pedological	Computer types, core memories and peripherals (list separately)	medium	low	medium	low
	Programmers (number)	"	"	"	"
	Average no. of years of education and experience	"	"	"	"

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Geological and geomorphological	Computer types, core memories and peripherals (list separately)	medium	low	medium	low
	Programmers (number)	"	"	"	"
	Average no. of years of education and experience	"	"	"	"
Land-use/land-cover	Computer types, core memories and peripherals (list separately)	medium	medium	medium	medium
	Programmers (number)	"	"	"	"
	Average no. of years of education and experience	"	"	"	"
PRIMARY PROCESSING					
Water cycle data Meteorological	Percentage recording charts digitized	high	high	high	high
	Percentage daily computations carried out	high	medium	high	medium
Hydrological	Percentage recording charts digitized	"	"	"	"
	Percentage daily flows estimated	"	"	"	"
	Ratio of range of levels of flow measurement to total range	high	high	high	high
	No. of sediment laboratories	"	"	"	"
	No. of water quality laboratories	"	"	"	"
Hydrogeological	Percentage recording charts digitized	medium	high	medium	high
	Percentage 1-3-5 days regular observations	"	"	"	"
	Percentage temperature and water quality observations	"	"	"	"

SUGGESTED EMPHASIS LEVELS FOR DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Physiographic data					
Topographical	Percentage area with aerial photography for which contours have been traced	high	high	high	high
Pedological	Percentage area for which field work has been processed	high	high	medium	medium
Hydrological	Percentage area for which field work has been processed	medium	high	medium	high
Land-use/land-cover	Percentage imagery (including Landsat) for which rectification and interpretation have been carried out	medium	high	medium	high
PUBLICATIONS					
Water cycle data published regularly					
Meteorological	Publication interval (months)	high	high	high	high
	Publication lag (months)	"	"	"	"
Hydrological	Publication interval (months)	high	medium	high	medium
	Publication lag (months)	"	"	"	"
Hydrogeological	Publication interval (months)	medium	medium	medium	medium
	Publication lag (months)	"	"	"	"

SUGGESTED EMPHASIS LEVELS FOR DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Physiographic data					
Topographical[3)]	Topographic maps				
	1:1 000 000 maps published				
	Total area	high	high	high	high
	Percent of country	"	"	"	"
	Publication lag	"	"	"	"
	1:250 000 maps published				
	Total area	medium	medium	medium	medium
	Percent of country	"	"	"	"
	Publication lag	"	"	"	"
Pedological	Pedological maps				
	1:1 000 000 maps published				
	Total area	high	medium	medium	low
	Percent of country	"	"	"	"
	Publication lag	"	"	"	"
	Studies of 1:1 000 000 maps				
	yes/no	"	"	"	"
	Percent of country	"	"	"	"
	1:250 000 maps published				
	Total area	"	"	"	"
	Percent of country	"	"	"	"
	Publication lag	"	"	"	"
	Studies of 1:250 000 maps				
	yes/no	"	"	"	"
	Percent of country	"	"	"	"

SUGGESTED EMPHASIS LEVELS FOR DATA STORAGE, PRIMARY PROCESSING AND PUBLICATION (contd.)

TYPE OF ACTIVITY ASSESSED	EVALUATION ELEMENT	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Physiographic data					
Geological and hydrogeological	Geological and hydrogeological maps				
	1:1 000 000 maps published				
	Total area	medium	high	medium	high
	Percent of country	"	"	"	"
	Publication lag	"	"	"	"
	Studies of 1:1 000 000 maps				
	yes/no	"	"	"	"
	Percent of country	"	"	"	"
Land-use/land-cover	Land-use land-cover maps				
	1:1 000 000 maps published				
	Total area	medium	high	medium	high
	Percent of country	"	"	"	"
	Publication lag	"	"	"	"
	Studies of 1:1 000 000 maps				
	1:250 000 maps published				
	Total area	"	"	"	"
	Percent of country	"	"	"	"
	Publication lag	"	"	"	"
	Studies of 1:250 000 maps				
	yes/no	"	"	"	"
	Percent of country	"	"	"	"

Notes: 1) Fully catalogued data means data that can be located according to object, subject, space, time, quality and source.

2) If one computer is used for a number of water cycle components and/or types of auxiliary data, this should be stated and the data completed only for one water cycle component or type of auxiliary data.

3) Topographic maps 1:50 000 and 1:10 000 may be included depending on size of the country and also for particular hydrological studies (i.e. urban flood mapping).

APPENDIX VIII

SUGGESTED EMPHASIS LEVELS FOR AREAL ASSESSMENT

TYPE OF ACTIVITY EVALUATED	EVALUATION ELEMENT *	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Meteorological	Area for which annual isohyetal maps are available (% of total area)	medium	high	medium	high
	Validation error %	"	"	"	"
	Area for which seasonal isohyetal maps are available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which maps of statistical parameters of annual precipitation are available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which maps of statistical paramaters of seasonal precipitation are available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which maps of statistics of storm precipitation area available (% of total area)	high	high	high	high
	Validation error %	high	high	high	high
Hydrological	Area for which annual runoff map available (% of total area)	medium	low	medium	low
	Validation error %	"	"	"	"
	Area for which seasonal runoff map available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which maps of statistical parameters of annual runoff available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"

SUGGESTED EMPHASIS LEVELS FOR AREAL ASSESSMENT (contd.)

TYPE OF ACTIVITY EVALUATED	EVALUATION ELEMENT *	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Hydrological (contd.)	Area for which maps of statistical parameters of seasonal runoff available (% of total area)	medium	low	medium	low
	Validation error %	"	"	"	"
	Area for which rainfall-runoff models have been calibrated (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which inputs to rainfall-runoff models are available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which maps of annual soil moisture available (% of total area)	medium	high	medium	high
	Validation error %	"	"	"	"
	Area for which seasonal soil moisture maps available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which annual groundwater yield maps available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which seasonal groundwater yield maps available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"

SUGGESTED EMPHASIS LEVELS FOR AREAL ASSESSMENT (contd.)

TYPE OF ACTIVITY EVALUATED	EVALUATION ELEMENT*	EMPHASIS AND ACTIVITY LEVELS			
		SEDIMENTARY		NON-SEDIMENTARY	
		HUMID	ARID	HUMID	ARID
Hydrological (contd.)	Area for which groundwater models have been calibrated (% of total area)	medium	medium	medium	medium
	Validation error %	"	"	"	"
	Area for which inputs to groundwater models are available (% of total area)	"	"	"	"
	Area for which relationships between time series parameters and physiographic characteristics available (% of total area)	"	"	"	"
	Validation error %	"	"	"	"
	Area for which inputs into relationships between time series parameters and physiographic characteristics available (% of total area)	"	"	"	"

* Validation error is defined as the error obtained, for example, by split sample testing. In this the available data sample is split into two. One sample is used to calibrate the model (e.g. to trace the isohyets) and the other sample is used to estimate the errors as the difference between measured and estimated (e.g. from the isohyets).

APPENDIX IX

PROPOSALS FOR EMPHASIS AND REFERENCE* LEVELS CONCERNING USE OF WATER-RESOURCE DATA FOR PROJECTS

Water-resource characteristics / Water resource project element	Precipitation				Evaporation	River water levels			River flow				Channel chart			Sediment	Groundwater			
	Storms	Time Series	Snow	Quality		Time Series	Max.	Min.	Time Series	Max.	Min.	Quality	Cross section	Plane	Velo distr.		Levels	Yield	Hydr. char.	Quality
Modifiers of water balance	H 30	H 10	H 40		H 40				H 5	M 15	M 15						H 5	H 10	M 20	
Redistributors of water in space					M 50	H 5	H 10	H 5	H 5	H 10	H 10	H 20	H 5	H 5	H 5	H 20	H 5	H 10	H 20	H 25
Redistributors of water in time	M 25	10	H 40	H 25	H 30	M 10	M 15	M 10	H 5	M 15	H 10	H 20				H 20	H 10	H 20	H 20	H 25
Extractors or suppliers of water energy				M 25		H 5	H 10	H 5	H 5	M 15	H 10	M 25	M 5		M 5	H 20	H 10	H 20	H 15	H 25
Water confinors				M 25		H 5	H 10	H 5	M 5	H 10		M 25	M 5	M 5	M 5	M 30				M 30
Water relievers				M 25		H 5	H 10	H 5	H 5	H 10		M 25	M 5	M 5	M 5	M 20				M 30
Quality improvers at source	H 35	H 15	H 40	H 20	H 15							H 20	M 5	M 5	M 5	M 20	H 10	H 10	H 20	H 30
Quality improvers at use points									H 5	M 15	H 10	H 20	M 5	M 5	M 5	M 20	H 10	H 10	H 20	H 20
Water related legislation and standards	M 40	M 20	M 50	M 30	M 40	M 10	M 15	M 10	M 10	M 15	M 15	M 25	M 20	M 20	M 20	M 30	M 20	M 20	M 30	M 30
Zoning	M 40	M 20	M 50	M 30	M 40	M 10	M 15	M 10	M 10	M 15	M 15	M 25	M 5	M 5	M 5	M 30	M 20	M 20	M 30	M 30
Insurance	H 25	M 10					H 10	H 5	M 5	H 10	H 10	H 20					H 10	M 20	M 20	
Flow and water quality forecasting	H 25	H 10	H 40	H 20	M 30	H 5	H 10	H 5	H 5	H 10	H 10	H 20	M 10		M 10		H 10	H 10	H 20	H 20

* Reference levels given as tolerance limits in percent, except for water levels where the limit is given in cm.

APPENDIX X

EXAMPLE OF INFORMATION AND EMPHASIS LEVELS ON EDUCATION AND TRAINING IN WATER RESOURCES AND RELATED AREAS

Course	No. OF SCHOOLS		DURATION (months)	PREREQUISITE EDUCATION	AVAILABLE		AVERAGE ANNUAL ENROLMENT	REMARKS	EMPHASIS OF INDEX			
	REGULAR	OCCASIONAL			INSIDE THE COUNTRY	OUTSIDE THE COUNTRY			ARID		HUMID	
									SED.	N.SED.	S.	N.SED
Meteorological observer	1+	2 in 10 years+	regular:3 yrs. occas.:3 mos.+	12 yrs pre-university	yes+	no+		Indicate approximate periodicity	h	h	h	h
Hydrological observer									l	m	h	h
Hydrogeological observer									h	l	h	l
Meteorological technician									h	h	h	h
Hydrological technician									l	m	h	h
Hydrogeological technician									h	l	h	l
Surveyor (technician level)									m	m	h	h
Pedological technician									h	h	m	m
Geological technician									h	h	m	m
Computer technician									m	m	m	m
Meteorologist									h	h	h	h
Hydrologist									l	m	h	h
Hydrogeologist									h	l	h	l
Hydraulician									m	m	m	m
Surveyor									m	m	h	h
Pedologist									h	h	m	m
Geographer								With hydrometeorological background	m	m	m	m
Engineer Bachelor's Degree Master's Degree Doctorate												
Systems analyst									m	m	m	m
Mathematician									m	m	m	m
Statistician									m	m	m	m
Computer scientist									m	m	m	m
Telecommunication technician									m	m	m	m

APPENDIX XI

EXAMPLE OF INFORMATION ON PROGRAMMES OF R AND D INSTITUTIONS

INSTITUTION	SUBJECTS	STATUS		BUDGET ALLOCATION ($US)	DURATION
		IN PROGRESS	PLANNED		
Institute of Hydrology	Techniques for rapidly inventorying natural water resources			10 million	5 years
	Development of improved rainfall runoff models			2 million	3 years
	etc.				
	etc.				
Institute of Forest Research	Influence of deforestation on hydrologic water balance			15 million	10 years
	Determination of type of soil through remote sensing techniques			3 million	5 years
	Relationship between forest fires and hydrometeorological conditions			3 million	5 years
	etc.				
	etc.				
Centre for Remote Sensing	Improvement of techniques of estimation of areal distribution of precipitation using remote sensing			20 million	10 years
	etc.				
	etc.				