WORLD CLIMATE PROGRAMME

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WORLD CLIMATE PROGRAMME

INFORMAL PLANNING MEETING ON WORLD CLIMATE PROGRAMME - WATER

(GENEVA, 2-6 FEBRUARY 1981)

W0RLD METE0R0L0GICAL 0RGANIZATI0N

The WCP consists of four major components implemented by WMO in conjunction with other international organizations:

- The World Climate Research Programme (WCRP)
- The World Climate Applications Programme (WCAP)
- The World Climate Impact Studies Programme (WCIP)
- The World Climate Data Programme (WCDP)

TABLE OF CONTENTS

1. OPENING OF THE MEETING

1.1 The Informal Planning Meeting on World Climate Programme - Water was held at WMO Headquarters, Geneva from 2 to 6 February 1981. It was organized jointly by Unesco and WMO with the sponsorship of UNEP and ICSU. The meeting was attended by international experts in hydrology, water-resource systems and climate modelling. A full list of participants is presented in Annex 1 to this report.

1.2 The meeting was opened by its Chairman, Professor B. Döös, at 10 a.m. on Monday 2 February 1981. In his opening remarks, Professor D66s stated that the purpose of the meeting was to receive advice from experts on the form and content of activities which might be undertaken within the World Climate Programme (WCP) in relation to water. Particular emphasis was placed on the need for a series of clearly defined, interesting and viable projects which could be implemented at national, regional or international level. Specific note was taken of the need to avoid any duplication of the work in the field of water already being undertaken by many international organizations but rather to build upon this work and coordinate with such activities.

2. ORGANIZATION OF WORK AND APPROVAL OF THE AGENDA

2.1 The agenda followed by the meeting is given in Annex 2 to this report.

2.2 The meeting discussed all matters as one committee but the first drafts of the material which appear in the annexes to this report were prepared by small ad-hoc groups.

2.3 While the meeting had at first been foreseen as concentrating on water aspects of the World Climate Applications Programme, it was felt that the hydrology and water-resource aspects of the WCP should be considered as a whole under the title World Climate Programme - Water. The meeting therefore agreed to discuss and make proposals concerning water aspects of the whole of the WCP and not just those relating to applications.

3. REVIEW OF THE WORLD CLIMATE PROGRAMME

3.1 The meeting was informed of the overall structure of the WCP and the aims of its four component programmes, namely:

World Climate Research Programme (WCRP)
World Climate Applications Programme (WCAP)
World Climate Impact Studies Programme (WCIP)
World Climate Data Programme (WCDP).

Reference was made to the different nature and administrative structure of the four programmes and information was provided on the progress that had been made in their planning and implementation.

3.2 Stress was laid on the close relationship that existed between the four programmes and the fact that it would be not only difficult but undesirable to draw clear dividing lines between them. The decision recorded in paragraph 2.3 above reflects this concern.

3.3 The meeting recognised the importance of identifying the interfcces between WCP-Water, WCP-Food and WCP-Energy and reflected this in its recommendations.

3.4 The meeting was informed of the International Hydrology and Water Science Programmes of Unesco, the Hydrology and Water Resources Programme (HWRP) of WMO and of a number of WMO field projects in water which were of relevance to discussions on pilot or demonstration projects. Particular note was taken of the Agrhymet Project and the potential value of its data bank and on-going regional activities in climatology. The meeting was also informed of the discussions at the JSC Study Conference on Land Surface Processes in Atmospheric General Circulation Models (Greenbelt, January 1981) and of the recommendations of the conference relating to water.

4. AIMS AND OBJECTIVES OF WCP-WATER

4.1 In reviewing the WCP in its broad perspective the meeting took note that the relationship between climate and the water-resource system on the earth is unique in the sense that parts of the hydrological cycle, such as precipitation and evaporation, are simultaneously inherent parts of the climate system and are important characteristics of the latter. With this in mind, it made proposals for the overall goal and objectives of WCP-Water

4.2 The overall goal of WCP-Water was stated as being: To meet more effectively the socioeconomic needs which depend on water-resource systems, through the improved application of climate data and information.

4.3 The four objectives of WCP-Water were identified as:

A. To enhance our understanding of the relationship which exists between climate and water resources and which is based on hydrological processes

B. To make more effective use of climate information in water-resource management

C. To enhance our understanding of the impact of climate variability and change on water resources

D. To improve the availability of data required to achieve the objectives of the World Climate Programme – Water

These are presented in more detail in part 2 of Annex 3 to this report.

4.4 The projects described below are presented as preliminary proposals for consideration by all bodies involved in the planning of WCP-Water.

5. PROGRAMME OF ACTION FOR WCP-WATER

5.1 The meeting prepared a Preliminary Plan for WCP-Water which is attached as,.Annex 3 to this report. It was recognized that a comprehensive programme of action for WCP-Water would need not only to cover the four component programmes of the WCP but would also have to take into account a number of other factors, including the interagency and interdisciplinary nature of much that should be done. Accordingly, a series of important general recommendations were made concerning the aims of WCP-Water and the activities that should be undertaken to achieve them. These are presented in part 3 of Annex 3. Most important amongst these is the need to ensure close co-ordination between the activities under WCP-Water and those under WCP-Food, WCP-Energy and other sectorial fields of WCP.

5.2 The meeting then developed a series of seven activities in which it felt work should be concentrated. These are:

1. Application of climate forecasts and information in the operation of water-resource systems
2. Modelling of the hydrological cycle
3. Inventory of water resources and their dynamics
4. Studies of climate variability using hydrological data
5. Studies of the influence of climate variations on water resources
6. Societal implications of climate impact on water resources
7. Transfer of knowledge and technology.

Activity 7 is seen as a supporting activity for 1 to 6.

5.3 Specific proposals for projects were developed under each activity, these being described according to a standard format.

5.4 A fuller description of the seven activities and the projects finally recommended is presented in part 4 of Annex 3. The meeting noted that this set of projects, and indeed the list of activities, represented a preliminary plan for the WCP-Water. It therefore recommended that all bodies involved or interested in the WCP be invited to comment on them and propose additions or amendments. It was recognized, in particular, that projects relating to WCRP and WCIP, more specifically those under activities 2 and 6, should be tailored to suit the work being undertaken or planned by the Joint WMO/ICSU Scientific Committee and LNEP respectively for these two component programmes.

5.5 The meeting further noted that the technical and scientific work for most of the projects would need to be undertaken at national level by government agencies or research institutes. It therefore recommended that countries be invited to nominate national bodies which might wish to be associated with individual projects so that detailed plans for their implementation could be drawn up in consultation with all who might wish to contribute to the work.

5.6 Some of the proposed projects focus on specific aspects of the climate/ water-resource relationship while others are more general. Likewise the geographical extent of projects differ: some being international and others tied to specific basins. The meeting emphasized that projects described in relation to specific basins were by no means intended to be exclusive and proposals for identical or similar parallel projects in other locations should be solicited.

5.7 The meeting tentatively identified, project by project, the co-operation of the international organizations in the projects mentioned in the Preliminary Plan as follows:

PROJECT NO.	UN BODIES AND AGENCIES AND OTHER INTERNATIONAL ORGANIZATIONS								
	UNEP	FAO	UNEP	UNESCO	WHO	WMO	WORLD BANK	IIASA	ICSU
1.1			x		x				
1.2									
1.3					x				
1.4									
2.1				x		x			
2.2				x		x			
2.3	x	x		x		x		x	
2.4				x		x			
3.1				x		x			xx
3.2						x			
3.3				x		x			x
4.1						x			xx
4.2						x			
5.1		x		x		x		x	
5.2				x		x			
5.3				x					
5.4	x			x		x	x		
6.1	x		x	x		x			
6.2		x			x	x		x	x
7.1									
7.2	x			x		x			x
7.3									
7.4				x		x			
xx Particular reference is made to IAHS in relation to these projects.									

6. CLOSURE OF THE MEETING

6.1 The Chairman closed the meeting at 1 p.m. on Friday, 6 February 1981.

6.2 In his closing remarks Professor Döös expressed his satisfaction with the outcome of the meeting, in particular with its success in defining clear objectives for WCP-Water and proposing a series of very concrete proposals for ways in which these might be met. He emphasized the advantages to be gained by keeping the plan for WCP-Water flexible and maintaining close liaison with all interested international organizations, in particular Unesco, LNEP and ICSU. As regards WMO itself, Professor Döös expressed confidence in the valuable role that the Commission for Hydrology could play in support of the WCP.

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ANNEX 2

AGENDA

1. OPENING OF THE MEETING

2. ORGANIZATION OF WORK AND APPROVAL OF THE AGENDA

3. REVIEW OF THE WORLD CLIMATE PROGRAMME

4. AIMS AND OBJECTIVES OF WCP (WATER)

5. PROGRAMME OF ACTION FOR WCP (WATER)

6. CLOSURE OF THE MEETING

PRELIMINARY PLAN FOR WCP-WATER

(February 1981)

CONTENTS

PRELIMINARY PLAN FOR WCP-WATER

1. INTRODUCTION

1.1 The World Climate Programme (WCP) was adopted by the Eighth World Meteorological Congress in 1979. It has four component programmes, namely:

World Climate Research Programme (WCRP)
World Climate Applications Programme (WCAP)
World Climate Impact Studies Programme (WCIP)
World Climate Data Programme (WCDP)

1.2 There is a unique relationship between climate and the water-resource system on the earth in that parts of the hydrological cycle, such as precipitation and evaporation, are simultaneously inherent parts of the climate system and are important characteristics of the latter. There are therefore hydrological and water-resource aspects of all four of the above component programmes. All water related activities under the WCP need to be closely coordinated and for this reason they are grouped under the general title World Climate Programme - Water (WCP-Water).

1.3 The Preliminary Plan for WCP-Water presented below was developed by an Informal Planning Meeting on World Climate Programme - Water which was held at WMO Headquarters in Geneva in February 1981. The aim of this meeting was to advise on the form and contents of activities which might be undertaken within the WCP in relation to water, and to make proposals for a series of clearly defined, interesting and viable projects which could be implemented at national, regional and international level.

2. GOAL AND OBJECTIVES

2.1 The overall goal of WCP-Water may be stated as being:

TO MEET MORE EFFECTIVELY THE SOCTO-ECONOMIC NEEDS WHICH DEPEND ON WATER-RESOL)RCE SYSTEMS, THROUGH THE IMPROVED APPLICATION OF CLIMATE DATA AND INFORMATION.

In support of this goal, four objectives (A, B, C and D) may be identified. These are presented below.

2.2 OBJECTIVE-A: TO ENHANCE OUR UNDERSTANDING OF THE RELATIONSHIP WHICH EXISTS BETWEEN CLIMATE AND WATER RESOURCES AND WHICH IS BASED ON HYDROLOGICAL PROCESSES.

2.2.1 On a general level, the relationship between climate, hydrology and water resources seems to be so self evident that it attracts little attention beyond the obligatory exposition of the hydrological cycle. The interactions are often either not included at all or are included only implicitly and the inputs from the sister sciences are treated in a cavalier fashion, often as "independent" variables which remain immune from whatever is going on in the "main" science, whichever of the three it happens to be. The physical unity of the three component processes of the water cycle is thus artifically broken up and the neglect of the feedbacks introduces uncertainty which leads to the corruption of the physical relationships by a high level of noise.

2.2.2 The objective is to remedy this situation by an explicit introduction,' into each of the three sciences, of the physical linkages between them. This coupling is necessary in the climate/water-resource context because

(i) climate affects water resources through hydrology which acts as a transfer mechanism, and

(ii) water resources affect the climate by the alteration of the natural hydrological processes, e.g. by the redistribution of water in both space and time.

2.3 OBJECTIVE-B: TO MAKE MORE EFFECTIVE USE OF CLIMATE INFORMATION IN WATER-RESOURCE MANAGEMENT.

Three specific areas can be identified under this general objective.

2.3.1 To improve the use of climate information in the planning and design of water-resource systems. Present practice relies mainly in analysis of available hydrological data, especially streamflow data. Improved techniques are needed to use not only available hydrological data but also climatological and paleoclimatological data and climate models.

2.3.2 To improve the use of climate information in the operation of water-resource systems. Present practice often relies on fixed operating policies that do not use all of the information that could be made available on the possible short-term future availability of water supplies. There is a need for improved methods to address the uncertainty concerning the future levels of such supplies, especially for extended periods. These methods should consider current hydrological conditions, historical climate variations and long-range weather forecasts or short-range climate forecasts.

2.3.3 To improve the application of climate information in meeting the-water needs-of-society. These needs may be arranges in five catagories:

- Increased food production
- Increased drinking water supplies
- Improved environmental health conditions
- Disaster mitigation and prevention
- Increased industrial production and transport.

This area of activity should provide the basis for close links between WCP-Water, WCP-Food and WCP-Energy.

2.4 OBJECTIVE-C: TO ENHANCE OUR UNDERSTANDING OF THE IMPACT OF CLIMATE VARIABILITY AND CHANGE ON WATER RESOURCES.

2.4.1 This objective is related to the development of our knowledge and awareness of the interactive relations between climate variability and change on the one hand and human socioeconomic activities in respect of water-resource management on the other. In this statement recognition is given to the central role of water to man's activities and to the fact that sudden or extreme changes can have a significant impact on national economies and human welfare, both directly and through the interaction of their effect on water resources.

2.4.2 An important object of impact studies must be to introduce climate considerations into the formulation of national policy alternatives so as to mitigate against the adverse effect of climate change and variability on the supply and quality of water resources and so as to take advantage of any benefit that may accrue.

2.4.3 Climatologists are able to speculate upon possible climate futures. Hydrologists are not, as yet, in such a strong position to translate these climate futures to predict the mean value and probability distributions of those hydrological variables that are important to water-resource decision making. Efforts should therefore be made to strengthen the modelling capabilities of hydrologists to enable them to deduce such mean values and probability distributions.

2.5 OBJECTIVE-D: TO IMPROVE THE AVAILABILITY OF DATA REQUIRED TO ACHIEVE THE OTHER OBJECTIVES OF THE WORLD CLIMATE PROGRAMME - WATER.

2.5.1 In order to fulfill the Objectives A, B and C activities will need to be undertaken at national, regional and international levels. These activities will each have demands for data of many types. In addition, the data requirements of the individual projects will often be very different.

2.5.2 Some projects will be undertaken solely at national level, in such cases guidance may be provided as to the types of data that will be needed and how they might be collected and made available. For projects at regional and international level sets of data may need to be collected, exchanged and possibly stored at some appropriate location. In addition there may be a need for guidance on this work.

2.5.3 In the wider context, those needing data should be aided

(i) by offering information and advice as to where such data are to be found, and
(ii) by encouraging those in a position to do so to collect and make available the data required.

2.5.4 The general types of data required to meet the objectives are summarized in the Appendix to this plan.

3. SELECTION AND EXECUTION OF PROJECTS

3.1 Principal Features of Projects

3.1.1 There are a number of common features which should distinguish projects that are selected for inclusion under WCP-Water. Among these are:

(i) They should be associated with the relationship between the climate, the hydrological cycle and water resources;

(ii) They should cover between them a wide range of topics, including environmental and socioeconomic as well as purely physical aspects, and should not concentrate only on specific areas;

(iii) They should include efforts to fill gaps in existing methodologies and to overcome difficulties in the transfer and application of these methodologies, and

(iv) They should be closely tied to the practical realities in countries, especially those with limited resources of data, manpower and computing.

3.1.2 There are further points which should be considered not only in the selection of projects, but also in their execution. These include:

(v) The need to consider not only present and post climate conditions, but also future climate variability and change;

(vi) The importance of checking for variations due to differences in climatic region, basin size and geomorphological characteristics and level of socioeconomic development;

(vii) The need to consider the planning, the design and also the operation of water management systems;

(viii) Recognition should be given to the fact that teleconnections within the climate system can affect elements of the hydrologic cycle in various parts of the globe;

(ix) The importance of demonstrating the relevance of projects to the socioeconomic development of countries and, in particular, to the following needs:

(a) Need for food
- agricultural water supply, irrigation projects and inland fisheries

(b) Need for drinking water
- urban and rural water supply

(c) Need for health and security
- flood forecasting and control systems
- systems for the prediction and management of water quality

(d) Needs of industry and commerce
- industrial water supply projects - hydropower projects
- inland navigation projects.

3.2 Elements of the Hydrological Cycle

3.2.1 Streamflow is certainly the most clearly identifiable factor directly influencing at national level such economic activities as large scale irrigation, energy production, municipal water supply and flood prevention. Streamflow is the residual of the land water balance which remains after the other components, such as evapotranspiration, soil moisture and groundwater recharge, have been satisfied. Thus the study of the other elements of the hydrological cycle in relation to climate is implicit in the study of streamflow.

3.2.2 Any apparent emphasis on streamflow should not be interpreted as meaning that there are not other hydrological or water-resource factors which are influenced by climate and which can have major repercussions on the economic and social life of a region. Two important elements of the hydrological cycle in this respect are soil moisture and groundwater. It is the relation between precipitation and soil moisture that governs the growth of crops and pastures in non-irrigated areas on which the subsistence of very large numbers of people depend, in particular in semiarid areas. Likewise, groundwater levels can be influenced to a high degree by climate variability and are of vital importance to communities which are very dependent on them. These problems are expected to be of particular interest not only to WCP-Water but also to WCP-Food.

3.3 Priorities

3.3.1 In the development and implementation of projects under WCP-Water, emphasis should be placed on those which can be undertaken early and which require little or no additional funding on the part of WMO and associated international organizations.

3.3.2 In addition, the link between the food, water and energy sectors of the WCP is of vital importance if the overall programme is to achieve its aims. Inter-disciplinary projects should therefore be encouraged. In the context of WCP-Water this emphasises the importance of projects relating to:

- increased food production, through agricultural water supply and irrigation;

- improved environmental health conditions, in terms of urban and rural drinking water supply and sanitation;

- increased energy production, through the development of hydropower projects.

Many of these needs are met by water-resource systems which frequently include reservoirs, the design and operation of which depend upon a knowledge of climate variability.

3.3.3 With regard to the above, it should be noted that the manner in which we must now view our energy and food futures demands a better knowledge of climatic fluctuation, in order to reduce the vulnerability of society to the adverse effects of such fluctuations and to take advantage of any benefit that climatic variation or change may offer.

4. PROPOSED ACTIVITIES AND PROJECTS

4.1 The projects proposed for inclusion in WCP-Water are each related to one of a series of activities numbered 1 to 7. The projects are numbered according to the activity to which they are related e.g. 1.1, 2.3 and 7.4. Each project is described in a standard format under five items which are as follows:

1. Relationship to the objectives of WCP-Water
2. Results to be expected
3. Work to be done
4. Proposals as to who might undertake and/or sponsor the work
5. Comments on the feasibility of the project.

4.2 Entries under item 4 above are only in very general terms. It is expected that these will be specified in more detail in the light of comments and, more particularly, offers received.

4.3 Activity 7 has been included with the other six for ease of presentation and reference. It should be noted, however, that it is quite unlike the others in the nature of its projects and is best considered as a supporting activity to the other six which are of a more technical nature.

ACTIVITY 1. APPLICATION OF CLIMATE FORECASTS AND INFORMATION IN THE OPERATING OF WATER-RESOURCE SYSTEMS

Long range weather outlooks for periods of one to three months are being prepared, but improved methods of formulation and application are needed for these to be of significant value in the operation of water-resource systems. Also, improvements in the forecasting technology would be desirable for not only the short term but also for the long term extending beyond one year. Since many water-resource systems operate on a water year basis, the climate forecasts under consideration are limited to this time frame. Because of uncertainty in the forecasts, water-resource applications will need to take a probabilistic approach and future enhancements to climate forecast technology should explore the types of probabalistic methods that could be applied in practice.

The results of this activity should include:

- Improved methods for climate forecasting for monthly and seasonal periods

- Methods for applying climate forecasts in water-resource management

- Substantial evidence of the value of weather and climate information in the operation of water-resource systems.

Project 1.1 Pilot Study of Potential for Climate Forecast Applications to Hydropower, Irrigation and Flood Control in the Yamuna River Basin, India

1. Relates to Objectives B, C and D.

2. To aid in the improved use of water for specific purposes, the manager requires accurate forecasts of water volumes on an annual basis with updates each month. Models and/or methodologies developed for WCP-Water could be tested and evaluated in the Yamuna River Basin. The Yamuna Basin offers the possibility for one of a number of projects of this nature which might be undertaken.

3. Using the hydrological data available at the study area, develop operating plans to optimize the use of water for the specified purposes. Using the climate data available as inputs to climate models, estimate annual runoff and prepare annual operating curves and compare results.

4. National agencies with consultant support from international organizations.

5. Once the methodologies and models have been developed, some training on their use will be required. Since there is no requirement for additional major items of equipment, costs should be relatively low.

Project 1.2 Initial Application of Monthly Weather Outlooks in Water Supply Operations in the United States

1. Relates to Objectives A, B and D.

2. Monthly weather outlooks are made by the U.S. National Weather Service. This can lead to a conditional climatology appropriate to the present state of the climate system. This conditional climatology could then be used as input to hydrological models to produce an ensemble of possible future streamflow hydrographs which would be used to consider reservoir operations alternatives, to perform risk analyses, and to help decision-makers understand the range of possible options regarding water availability.

(i) Discussion of issues in applying climate forecasts in water-resource management

(ii) Discussion of issues in climate forecasting

(iii) Example application of monthly weather outlooks in operation of water-resource system

(iv) Specific suggestions for future research in climate forecasting

(v) Specific suggestions for future research in applying climate forecasts in water-resource management.

3. Apply U.S.A. monthly weather outlooks to streamflow forecasting in the U.S.A. and work with local water authorities on the application of this information in their operations.

4. National (federal, state and local) agencies in cooperation with interested international organizations.

5. Work on the project in the U.S.A. would require policy approval at national level.

Project 1.3 Use of Climate Dependent Factors to Foreshadow Drought Incidence

1. Relates to Objectives B, C and D.

2. This project would prove or disprove the efficacy of the several drought forecasting schemes that have been proposed from time to time. A forecast as understood by a meteorologist is a more or less deterministic exercise in which he traces forward from time 'now' to time 'now + t' using physics based principles. However, some workers have suggested more statistical approaches which can extend 't' considerably. These capitalise on some 'high inertia' features of the atmosphere-ocean-land phase of the cycle e.g. sea surface temperature, snow, aquifer level, jet stream location, ITCZ intensity and location. The forecast is, of course, an inexact one which is why the word "foreshadow" is used in the title but any information is useful in the context of drought.

3. Publicize the available methods (such as those in WMO and Unesco publications) and encourage their use by agencies.

4. International organizations to collate experience after a five-year trial.

Project 1.4 Study of Potential for Monthly and Seasonal Climate Forecasts and Applications for the Sahel

1. Relates to Objectives B, C and D.

2. Extended forecasts beyond the anticipated development of synoptic situations, find their basis in the study of variability of climate on a monthly or seasonal basis. Forecasts over a period varying from one to three months7 have practical applications in the assessment of possible flood magnitudes and drought severities, They also meet the essential requirements of rain-fed agriculture, in the operation of seasonal storage reservoirs and in the management of water supply and other undertakings dependent upon natural streamflow and lake conditions.

The forecasts are evidently the more necessary in those areas which experience considerable inter-annual variations in monthly and seasonal expectations. Whilst compounding the problem of formulating forecasts, it is considered to be in a region such as the Sahel that a particular study should be undertaken.

3. Utilising the available synoptic, agrometeorological, climatological and hydrological data base in the Sahel, the project is to study the potential for forecasts of water-resource availability over periods of one to three months, and to study the practical application of such forecasts.

4. The Agrhymet Centre, Niamey, provides an appropriate infrastructure, including the necessary data base and computer facilities. The activity would be a logical extension of an existing responsibility to undertake climate monitoring in the Sahel region.

5. Support to the project might be provided under existing sponsorship.

6. No problem, except that the infrastructural facilities are still in the process of installation. In particular, final establishment of the data bank cannot be foreseen until around 1983.

ACTIVITY 2. MODELLING OF THE HYDROLOGICAL CYCLE

The quantitative coupling of climate, hydrology and water resources can be best achieved within the framework of mathematical models of the hydrological cycle. In principle the types of such models cover a very wide spectrum, ranging from empirical relationships to causal (i.e. physically based) formulations, both subject to greatly varying levels of sophistication and scales in time and space. There is, or should be, no conflict between empirical and causal approaches in the sense that a correct empirical relation cannot be contradicted by the result of a correct causal model; there is, however, a definitive hierarchical relationship between these: the empirical model mostly states the observed facts, while a causal model attempts to explain why they take on the observed states and forms.

The explanatory power of causal models makes them especially attractive to the WCP-Water because it implies the potential of making inferences about events (and their impacts) which are beyond the range of past observations, as well as about the consequences of man's interference in the natural processes involved.

Thus, while recognizing the legitimacy of many categories of models, special emphasis should be put on those which are based on the dynamics of the physical processes involved including the feedbacks between the processes traditionally treated independently of each other. The inclusion of such feedbacks will call for innovative approaches, re-examination of the traditional dividing lines, and may even lead to partial restructuring of the education of climatologists, meteorologists, hydrologists, and water-resource specialists, with the aim of providing them with a broader basis of common background (see also Activity 7).

Project 2.1 Testing of Physically Based Water Balance Models on Selected Basins

1. Relates to Objective A.

2. More objective parameterization of component processes than is possible on the basis of common conceptual hydrological models; increased credibility of extrapolation under conditions of climate change.

3. Application of such models, preferably those incorporating climatehydrology feedback mechanisms, to given basins in different climate regions and comparison of the results with those obtained by conceptual and/or statistical models (an example of the type of models under consideration: Eagleson's model).

4. National agencies, projects of international organizations.

Project 2.2 Testing of Areal Evapotranspiration Models

1. Relates to Objective A.

2. More accurate estimate of areal evapotranspiration (as well as evaporation) and hence improvement of models of the hydrological cycle is one of their weakest links.

3. Application of various models in different climate regions on basins where the results can be checked by accurate water balance estimates over several years (minimum about 5 years).

4. National agencies, projects of internat ional organizations (National Hydrology Res. Institute of Envir. Canada could, for instance, provide manuals and computer programmes, both in FORTRAN and for a programmable HP pocket calculator, for the Morton model; other such models may be available through HOMS).

Project 2.3 Study of the Effects on the Climate of Mon's Intervention in the Hydrological Cycle

1. Relates to Objective A, in the establishment of the coupling water resources - climate.

2. Improvement of climate forcing functions in the modelling of the hydrological cycle under man's intervention. Results would help to separate manmade changes in the hydrological cycle from natural variability. This would be useful for the reconstruction of virgin conditions.

3. Collection of climate and hydrological information from areas subject to irrigation, alteration in land use (urbanization, deforestation), large water transfers, man-made lakes in different climate zones. Assessment of climate variables such as energy balance, albedo, and evapotranspiration, preferably before and after intervention. Control by bench mark basins where possible.

4. National and international organizations.

Project 2.4 Workshop on Approaches to and Possibilities for the Coupling of Physically Based Climate and Hydrological Models

1. Relates to Objective A.

2. Discussion and outline of practical ways for bringing together results of physical climate and hydrological modelling in order to accomodate the physical relationships (feedbacks) which are mostly being neglected in the current practice of modelling.

3. A workshop, of about one week's duration, with attendance limited to scientists and professionals actively working in physically based climate and hydrological modelling. The objective would be to propose specific research projects and approaches that seem promising for achieving the aim set out under item 2 above.

4. International organizations.

ACTIVITY 3. INVENTORY OF WATER RESOURCES AND THEIR DYNAMICS

An inventory of water resources, their supply, demands and their dynamics, is needed to provide hydrological data:

(a) to climate modelers for the validation of predictions

(b) to researchers studying climate change and variability

(c) for use in sensitivity studies and

(d) for the application to food, energy, economy and health problems.

One has to take into account the fact also that in the majority of developing countries elementary hydrological information is scarce and unreliable. For these regions appropriate transfer functions between climate, hydrological processes and water resources have to be derived and applied. The data are important as a basis for the establishment of relationships, therefore the hydrological inventory should be an essential part of the WCDP.

Project 3.1 <u>Collection of Hydrological Data on a Global Scale</u>

1. This project is related to all major Objectives of WCP-Water, but mainly to those described under Objectives A and D.

2. Deterministic General Circulation Models (GCM) need, as inputs and for validation, real data which are either not available or only exist in part. Worldwide hydrological data sets are required for use in WCRP as inputs for the GCM on climate or prediction scales and for the validation of the results. On the basis of these data, water balances can be evaluated, which are essential for the closure of GCM equation systems. They deliver information on the world-wide teleconnections of the global or regional hydrological cycles. The basic data sets on a daily period provide reality-control for deterministic climate models.

3. Two kinds of material should be collected and analyzed:

(a) long-term observation series on precipitation, evaporation, runoff, soil moisture, groundwater, snow and ice, water storages and temperatures, etc. World maps for annual and monthly averages should be derived. The analysis of hydrologic data should be condensed in a "World Hydrological Atlas", similar to the World Climate Atlasses.

(b) Daily hydrological information should be collected during a selected "International Hydrological Year". The density of data should be adequate for the analysis and transformation into areal averages of grid areas or into weighted grid point values, corresponding to the aim of Project 3.2.

4. The responsibility to organize the collection and to prepare instructions for the uniformity, network density and data analysis should lie with the LN agencies involved in WCAP. The project could be sponsored by non-governmental organizations.

5. Methodologies are developed by the existing world water balances, they can be extended and applied for the monthly, weekly or daily periods. The organization of a Hydrological Atlas can use the experiences of the world climate atlasses. The feasibility of an International Hydrological Year is of the same order as GARP, WWW. FGGE, IHD or similar world-wide activities in earlier years.

Project 3.2 <u>Transfer of the Hydrological Information of Stations and Basins to Grid Point or Average Grid Area Values</u>

1. Relates to Objectives A and D.

2. Methodologies for the transfer of hydrological information from station or basin values to grid point and grid area values. Global hydrological data sets or grid point and grid area bases.

3. General circulation and hydrological models depend on grid values for their parameter inputs. However, station networks and basins are congruent neither to the systematic meshes nor to the heterogeneity of topography, soils, vegetation, etc. This makes it difficult to transform the observed data to the needed forms. The hydrological information must be condensed to grid values on the mesh-width of the models. The methodologies have to be developed and global data sets have to be prepared for the averages and the corresponding real-time operational systems have to be organized.

4. International organizations should be responsible for the organization.

5. The feasibility depends on the realization of Project 3.1.

Project 3.3 <u>Collection of Historical Dcta for Providing Additioncl Climate Variables</u>

1. Relates to Objectives A and D.

2. Improvement of knowledge on climate variability and on sensitivity of water resources to such variability.

3. Collection of historical data, long-term hydrological observation series, flood marks, low-flow periods, ice cover, glacial behaviour, geomorphological indices, proxy series etc. for analysis in projects such as 4.1 and 4.2.

4. International organizations.

5. In several countries long observation series and hydrologiccl information are available.

ACTIVITY 4. STUDIES OF CLIMATE VARIABILITY USING HYDROLOGICAL DATA

An analysis of historical hydrological data and information and in particular of long hydrological time series should be undertaken in order to gain fuller knowledge of climate variability and a better understanding of the processes related to climate change.

Due to the close relationship between climate and hydrology, hydrological variables and the water resources are very strongly influenced by climate variations. With respect to these interactions, hydrological variables, such as surface runoff, can be considered as climate variables representing on a large scale the residual of precipitation and evaporation. In the past, hydrological data have not been used as much as they could as a basis for studying climate variability.

Project 4.1 Analyzing Historical Hydrological Information with Respect to Climate Changes

1. Relates to Objective A.

2. In many countries historical hydrological information (floods, low flow periods, river ice periods) is available. Such information can often be obtained from the archives of towns situated along large rivers. Other information can be found from special investigations (water accumulation from ice-core studies, ,floods from sediment probes, etc.). The material could be used for improving the knowledge on climate changes during post centuries. For this reason the material should be analyzed with respect to climate changes. The methodology to be used for such studies does not as yet exist.

3. A unified technique for analyzing and using historical hydrological information should be developed.

4. National research institutions could be invited to cooperate and an international symposium could be organized, sponsored by interested international organizcrtions.

5. Expenses should be low and many national institutions could contribute to the project.

Project 4.2 Analyzing Long Time Series of Hydrological Data with Respect to Climate Variability

1. Relates to Objective A.

2. In many countries long hydrological time series (discharges, water levels of rivers and lakes, etc.) are available. This material should be used for improving the knowledge on climate variability by being analyzed in that respect. To make the results of such studies in different countries comparable with each other, it is necessary to develop a unified method or to propose guidelines on the L)se of existing statistical methods.

3. Compilation of all existing recommendable statistical methods suitable for analyzing long time series, including recommendations on the kinds of data to be used.

4. An expert coil-ld be appointed to carry out this action. The analysis of hydrological time series with respect to climate variability using the recommended methods could be carried out by national research institutions. The expert could be sponsored by international organizations.

5. Expenses would be very low and many national institutions could contribute to the project.

ACTIVITY 5. STUDIES OF-THE INFLUENCE OF CLIMATE VARIATIONS ON WATER RESOURCES

The projects under this activity field are divided into three groups each prompted by a major observation about climate's impact on water resources.

Perhaps the most important outcome of any study in this area is a statement of the effect on water-resource decision variables of changes (real or, hypothetical) in climate inputs. This activity therefore includes all sensitivity analyses, whether on hydrological variables or on water-resource decision variables.

The second class of projects is inspired by the recent altered perspective on climate, i.e. that it is in continual motion. In reality the scale and direction of this motion is entirely determined by physical forces in the atmosphere, ocean, at the land surface and even astronomic factors. For convenience these motions are thought of as fluctuations about a local average value which in turn may fluctuate, vacilate irregularly, or even behave in a sinusoidal fashion. Movements which occur over a time scale of, say, 30 to 80 years are of particular importance as these are the planning horizons for current human activity in water-resource projects. Movements which occur over a 10-30 year time scale are important in that this is often the order of duration of our data base on which the scheme is designed. Within this time scale we conventionally ignore the possibility that part of the variation is due to movement and we tend to assign the total variability to the single causes of local fluctuation about a locally stable average value.

The final premise on which the projects in this activity field are founded .is the idea that there is a distinction between hydrological variables (such as aquifer level, runoff volume, flood frequency distribution), and water-resource decision variables (such as reservoir volume, hundred year flood, crop water use). In some cases the difference is slight, but in general it can be stated that hydrological variables are directly measured or derived from measurements with little intervention. Water-resource decision variables tend to be derived quantities somewhat remote from the basic measurements. Thus it is often the case that the relationship is sufficiently obscured so that one cannot simply estimate the effect of an alteration in the governing hydrological variables on the derived water-resource variable.

The projects under this activity therefore lie within the following three areas:

(i) sensitivity analyses of water-resource projects to climate change

(ii) statistical considerations relating to the possible difference between the climate in the design data period and the planning period

(iii) transfer functions between water-resource decision variables and the primary hydrological variables.

Project 5.1 Sensitivity of Water-resource Systems to Climate Variations

1. Relates to Objectives B, C and D.

2. The technical purpose of most water-resource projects is the management of the variability in time and space of the natural water supply resulting from the local climate so as to make it compatible with accepted socioeconomic needs. Preliminary results, based on a joint WMO/USA study using a catchment model to investigate the impact of climate change on mean streamflow, indicate that in semiarid climate conditions the response of a basin to relatively modest climate trends may be of considerable magnitude. Similar sensitivity studies should be conducted in various climate conditions and with well calibrated hydrological models.

3. Large basins in Asia, Africa and Latin America should be selected for the conduct of sensitivity studies of climate variations using the established methodology.

4. Basins with calibrated rainfall/runoff hydrological models should receive preference. These studies should be undertaken within the regular programmes and technical cooperation projects of international organizations. The action should be taken with the support of the WCP-Water.

Project 5.2 Sensitivity Analyses of Water-resource Systems to Various Climate Inputs Based upon Standardized Hydrological Diagrams

1. Relates to Objectives B and C.

2. The hoped for result will be an ability to predict the effect of climate variability on the hydrological response of a catchment. This project should focus on particular ways of presenting hydrological data that are of direct use in water-resource decision making such as storage-yield, flow-duration and flood-frequency diagrams.

3. Diagrams of the type envisaged can often be returned to a standard non-dimensional form which greatly reduced the regional variability. For example, in the U.K. the storage yield diagram has been reduced by judicious standardization to a single set independent of geology, climate and basin characteristics. However, it can be anticipated that different climate zones will show different curves and a relationship between the curve parameters and salient features of the climate will be visible. Thus the effect of a climate shift can be converted directly through the relationship to a consequent change in the diagram. This expectation is of course predicated in the belief that the internal balances that are responsible for the diagram taking the form that it does are not disturbed by the climate change. Further insight into this process will be obtained if well-calibrated conceptual models are used to supplement the data in producing the basic regional curves.

4. This project is best carried out by a single agency employing the results ,of organizations representing a variety of climate zones.

5. The success of such a proposal is not easy to judge as it is based on a belief which is hard to test. Some indications will come from the use of a conceptual model, but again, much depends on the reliability of the model in replicating internally the consequences of the change. Further indications may flow from applying the system to a split series both sides of a suspected climate change. Further indications may flow from applying the system to a split series both sides of a suspected climate change e.g. epochs of strong westerly circulation and epochs of blocking tendency. The results will, in any event, be valuable irrespective of climate change connotations.

Project 5.3 Transfer Functions between Hydrological Variables and Water-resource Decision Variables

1. This project is not exclusively tied to WCP-Water but is tied intimately to Project 5.1 and 5.2 and all other projects which are aimed at expressing the sensitivity of hydrological response to changes in the climate. It lies within the area of Objective C.

2. The results of the project will be general guidelines which will enable water-resource planners rapidly to evaluate the effect on their projects of possible climate or hydrologic changes by comparison with. a compilation of similar projects which have been more thoroughly analysed.

The project is not an identifiable separate task carried out at one centre but more a compilation 'of experience from projects for which hydrological variables are best correlated with the relevant water-resource decisions. The problem arises mostly in more complex projects where it is not clearly a single variable which controls the design (e.g. it is not only flood frequency which controls spillway design). The benefit comes from the ability to apply the results of the generalised sensitivity tests correctly to a new project without the necessity for carrying out a full individual evaluation.

3. Perform sensitivity tests on existing projects in their planning stage to determine, possibly by correlation, what element of hydrology is best related to the decision. For example, is the decision on irrigable area in a particular project a function of annual average runoff, variability of annual or seasonal runoff, 100-year return period drought, annual aquifer recharge, annual maximum soil moisture deficit, etc, etc.?

4. One international organization could collate the experience centrally. Field projects and/or funding banks may hold the information for individual projects. A number of international agencies might sponsor the work.

5. Harder to organize than to carry out.

Project 5.4 Trial Application of Methods of Design of Water-resource Projects which Relax and Generalize the Usual Assumptions of Climate and Hydrological Series Stationarity

1. Relates to Objective C.

2. The results that can be expected are more rational designs which will be less vulnerable to climate variabilities where the latter are not within the range of expectation based on the past.

3. Development of theoretical models and their application either as desk studies or to actual examples of techniques (an example of the revised design philosophy is to be seen in Fiering - Matalas in the N.A.S. report on Climate Climatic Change and Water Supply (J. Wallis 1977)). Particular attention ought to be given to the persistence phenomenon and the-success of existing models in encompassing both the low serial correlations and long run-lengths that are found in long hydrological and climatic time series.

4. Research establishments and consultants with support from international organizations.

5. Not an easy problem but an exciting one,

ACTIVITY 6. SOCIETAL IMPLICATIONS OF CLIMATE IMPACT ON WATER RESOLRCES

Societal implications of climate impact on water resources can be considered on several levels.

One is a simple statement of the type of impact that a climate change or variation h-as on the population of a given region either directly, through significant changes in hydrological characteristics, or indirectly through the projection of these water-regime changes into other areas of vital societal importance such as food, energy and health. It should be noted that the final impact might be positive or negative, not only as a function of, the climate change or variation itself but also as a consequence of the effect of the change in hydrological characteristics on societal interests. For example, flooding in moderation can be beneficial to some societies and reduced variability in streamflow could be detrimental.

A higher level involves the study of the adaptability of the given population to such impacts. For example with regard to the impact of droughts and floods, two major hypotheses have been posed (Warrick, 1980; Sugawara, 1978). The first states that persistent and adaptive societies, through their technological and social organization, lessen the impacts upon the resident population of frequent climate fluctuations or climate related events. The second hypothesis states that success in insulating a society from relatively frequent events of climate origin, where the society is becoming increasingly complex both socially and technically, will increase the vulnerability of such a society to natural (climate-related) as well as to social perturbations that occur much less frequently.

Project 6.1 Study of the Increasing Vulnerability Hypothesis

1. Relates to Objective C.

2. An assessment of the impact of climate on society through the hydrological transfer function of floods, using the hypothesis of increasing vulnerability.

3. A pilot project should be initiated to determine the impact of climate on society through the hydrological transfer function of floods, to assess the "increasing vulnerability" of society to infrequent flooding and to recommend appropriate action in the light of results. The construction of a historical record of flood occurrence assembling time-series data on flood damages and casualties, analyzing the flood occurrence/magnitude/damage/casualties function for evidence' of increasing vulnerability are tentatively proposed as the steps in such a pilot project.

4. This might be undertaken in a country with a developing social and economic environment. The proposal requires a multi-disciplinary effort. International bodies and agencies may wish to co-operate in such studies undertaken by interested governments.

5. Costs would be primarily associated with collection and collation of data.

Project 6.2 Mapping of Parameters for Various Scenarios of Climate Change

1. Relates to Objective C.

2. Guide for evaluation of impact on food (changes of crops or vegetal cover, needs for irrigation) and energy (hydropower potential, wood production), health (water supply, water-related disease occurrence).

3. Using models of the dynamics of the hydrological cycle on continental scales (when such models are available, e.g. Budyko), propose several plausible climate scenarios and estimate and map water-resource related variables (precipitation, evapotranspiration, runoff, soil moisture, temperature, groundwater levels, etc.). Present this mapped information in such a form as to indicate potential hazard or benefit areas for food, energy and health.

4. National agencies (e.g. NASA in the US), international organizations.

ACTIVITY 7. TRANSFER OF KNOWLEDGE AND TECHNOLOGY

Knowledge compiled and generated within the framework of the WCP-Water should be widely distributed throughout the world and applied by hydrologists and water-resource engineers who are involved in the planning, design and operation of water-resource projects.

There is therefore a need for two knowledge transfer processes. One horizontally, that is from specialist to specialist and from country to country; and another vertical transfer process from theory to practice. As the WCP-Water results are intended to be of immediate practical value the knowledge transfer process includes an educational programme.

All projects under this activity may be seen as being undertaken in support of those included under Activities 1 to 6.

Project 7.1 Publications

1. Relates to Objectives A to D as a supporting activity.

2. The results of the different projects in WCP-Water will be published and widely distributed.

3. The translation of results of the projects into a format and language that will lead to the application in practice by the intended reader. The readership may be either researchers, practicing engineers or the informed interested public, but there should not be any attempt to meet the needs of all these in any one publication.

4. The publications are to be prepared by the group responsible for the projects and edited by specialists familiar with the profile of the intended readers. The organization or body responsible for coordinating a project should sponsor the publications that emanate from it.

5. Cost depends on form of publication.

Project 7.2 Symposia and Workshops

1. Relates to Objectives A to D as a supporting activity.

2. In the framework of the WCP-Water special symposia will be organized in the course of programme execution to exchange results obtained by national institutions and make these known to the world at large and to report on progress.

3. Symposia in any of the fields of the water sciences may be used to introduce climate related items.

4. The special symposia to be convened by the organization sponsoring the specific projects and organized by the group responsible for the project. Sponsorship by international organizations.

5. Extensive use can be made of symposia and workshops already planned or foreseen by the national and international agencies involved.

Project 7.3 Scientific Information Exchange Systems

1. Relates to Objectives A to C.

2. Several of such systems exist or are in the process of being established, as for example the international documentation system on agricultural knowledge of FAO, the general scientific system of Unesco, the POETRI system for-water supply information planned within the framework of the International Water Supply and Sanitation Decade of WHO. The HOMS of WMO is also very important in this regard.

3. The WCP-Water should ensure that the knowledge and information generated by it will be introduced into existing national and international documentation and information systems. To this end, contacts will be established with national and international systems for information and technology transfer whether they be general or specialized for such areas as agriculture, health or energy. In co-operation with them, information will be tailored to suit their formats.

4. WCP with the organizations responsible for existing information systems and related national centres.

5. The project is feasable but will need much time. The effort necessary in formulating project results into system-compatible formats should not be underestimated.

Project 7.4 <u>Education and Training of Hydrologists and Water-resource Engineers in Climatology as Applied to the Design and Operation of Water-resource Projects</u>

1. Relates to Objectives A to C as a supporting activity.

2. There is a need for climatologists to know more about hydrology and for hydrologists to know more about climatology. This project concerns the latter aspect.

While it may be expected that the international research community will automatically and quickly respond to the new knowledge, it seems necessary to also actively promote the transfer of knowledge to practicing hydrologists and water-resource engineers as well as students in these fields.

The results expected from this activity are a gradual introduction of climate knowledge in the general curriculae for the training and education of water-resource specialists. In order to make it possible that the knowledge obtained at school is used in practice, the existing practicing specialists have also to be trained.

3. (a) provide teaching material to
   - (i) professors and teachers at (under) graduate level
   - (ii) professors and teachers at post-graduate level

   (b) organize international courses for hydrology and water-resource sciences and engineering professors

   (c) organize regional (post-graduate) courses for practicing hydrologists and water-resource engineers

(d) organize a seminar on the subject for directors and staff of the established international post-graduate courses in hydrology and water resources.

4. National bodies and international organizations.

5. The production of teaching material has to follow the work of the activities in the WCP. There will thus be a delay. The courses are to be given when the teaching material is at least available in draft. The first courses could be foreseen for 1984. The financing of the activities should not pose too many problems.

APPENDIX

PRELIMINARY SUMMARY OF DATA REQUIREMENTS FOR THE OBJECTIVES OF WCP-WATER

For Objective A the requirements are:

- Hydrological data to be used by climatologists for large-scale climate models
- Long series of hydrological observations for investigation of climate change
- Historical hydrological information to be used for reconstructing climates of the past
- Hydrological data relating to water-resource projects which may affect climate.

For Objective B the requirements are:

- Data concerning precipitation and all the climate elements which govern snowmelt and potential evapotranspiration (computed by energy balance)
- Data for the calibration of hydrological models
- Consistent data sets extending over long periods of time including data series either observed from direct observations or created for some part through simulation.

For Objective C the requirements are:

Data on anticipated trends of climate variables under various assumptions regarding possible changes in the climate and with the variables considered jointly.