

# WORLD CLIMATE PROGRAMME APPLICATIONS

FOURTH PLANNING MEETING

ON

WORLD CLIMATE PROGRAMME-WATER

PARIS, 12-16 SEPTEMBER 1988

WCAP – 5

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UNITED NATIONS EDUCATIONAL  
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ORGANIZATION

WORLD METEOROLOGICAL  
ORGANIZATION

The World Climate Programme launched by the World Meteorological Organization (WMO) includes four components:

- The World Climate Data Programme
- The World Climate Applications Programme
- The World Climate Impact Studies Programme
- The World Climate Research Programme

The World Climate Research Programme is jointly sponsored by the WMO and the International Council of Scientific Unions.

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## 1. INTRODUCTION

1.1 The fourth Planning Meeting on the World Climate Programme-Water was held at Unesco Headquarters, Paris, from 12 to 16 September 1988. It was organized jointly by Unesco and WMO with the purpose of reviewing progress in the implementation of existing projects under the World Climate Programme-Water (WCP-Water) and developing proposals for future activities. The list of participants is presented in Annex 1 to this report.

1.2 Mr. F.H. Verhoog and Mr. A.J. Askew, speaking on behalf of the Director-General of Unesco and the Secretary-General of WMO, opened the meeting at 10 a.m. on Monday 12 September 1988. They welcomed the participants and, in their opening remarks, stressed the value of planning WCP-Water activities not just as a joint exercise between WMO and Unesco, but also in conjunction with the programmes of other organizations such as UNEP, FAO and IAHS.

1.3 It was noted that the constituent bodies of WMO, in particular the WMO Congress and Executive Council, had been pleased to endorse the practice whereby WMO and Unesco jointly plan the water-related activities under the World Climate Programme and implement jointly or separately many of the related projects. Reference was made to the fact that the First and Third Planning Meetings on WCP-Water had been hosted by WMO in Geneva, in 1981 and 1985 respectively. Unesco having hosted the Second Planning Meeting in Paris in 1982, it was therefore very fitting that Unesco was now hosting the Fourth Planning Meeting.

1.4 Mr. J.C. Refsgaard accepted the invitation to act as chairman of the meeting. The agenda, as adopted, is given in Annex 2 to this report. The meeting discussed all matters in plenary, but much of the more detailed material contained in this report was first drafted in small ad hoc groups.

## 2. REVIEW OF RECOMMENDATIONS AND DECISIONS OF GOVERNING AND ADVISORY BODIES

2.1 Recommendations and decisions of the various governing bodies of the organizations concerned with activities and in the planning of the World Climate Programme (WCP) were noted by the meeting and are summarized below.

### Eighth WMO Congress

2.2 Eighth WMO Congress (Cg-VIII, 1979) first adopted the WCP as a major WMO programme encompassing a variety of activities directed to:

- aid countries in the application of climate knowledge to the planning and management of many aspects of man's activities, and
- foresee and warn of possible future variations and changes in climate, either natural or man-made, which may significantly affect the economic and social activities of mankind.

### Third Unesco/WMO International Conference on Hydrology and Scientific Bases of Water Resources Management

2.3 This conference was held in Geneva in March 1987. The conference reviewed the results achieved within the framework of the International Hydrological Programme (Unesco), Operational Hydrology Programme (WMO) and other activities of Unesco and WMO related to water resources since the second such joint Unesco/WMO conference which was held in 1981. The conference was also informed of activities carried out by many other governmental and non-governmental organizations in the field of water resources.

2.4 The meeting noted that the conference considered future programmes of Unesco and WMO in hydrology and water resources and adopted seven recommendations supporting future activities of WMO and Unesco in the field of hydrology and water resources. The recommendations most relevant to WCP-Water are as follows:

- Recommendation 2 calls for further implementation of WMO/Unesco international projects on water-resource assessment and for co-operation with competent organizations of the United Nations system.
- Recommendation 5 urges the Member States to encourage co-operation between those of their national institutions which are active in hydrology and water resources programmes and recommends, among other things, a further development of joint WMO/Unesco activities aimed at the integration of climate and hydrological studies under WCP-Water.
- Recommendation 6 calls for the maintaining of close co-operation of water-related activities under WCP with the IHP of Unesco.

### Tenth WMO Congress and the WMO Executive Council

2.5 Tenth WMO Congress (Cg-X, 1987), by its Resolution 8, recognized that fulfilment of the objectives of the WCP can provide the basis for significant improvements in the ability of members to provide services to national economic and social development. It expressed its satisfaction with the progress achieved in the development of detailed plans for different components of the WCP and their implementation, with the valuable co-operation of other international organizations, and decided that the substance of the WCP be as indicated in the Second Long-term Plan of WMO and that the WCP consist of the following four components:

- World Climate Data Programme (WCDP);
- World Climate Application Programme (WCAP);
- World Climate Impact Studies Programme (WCIP) - being implemented by the United Nations Environment Programme (UNEP);
- World Climate Research Programme (WCRP) - being implemented jointly by the International Council of Scientific Unions (ICSU) and WMO.

Congress agreed that WMO should continue to take the lead in the overall co-ordination of the World Climate Programme.

2.6 Recent findings in climate research, most notably as reported at the Villach Conference (Austria 1985), gave a new sense of purpose and urgency to studies of the link between climate and water resources in view of the sensitivity of these resources to climate variability. The Commission for Hydrology (CHy) and other bodies were seen by Cg-X as having made valuable inputs to water-related activities under the WCP, these being grouped for convenience under the heading WCP-Water. Congress called for this inter-programme support to be continued and, where appropriate, strengthened.

2.7 The impact of man's activities on the natural environment were seen by Cg-X as being a recurrent cause for concern. New dangers, frequently involving the aquatic environment of lakes, rivers and groundwater, have been identified by many experts and scientific bodies, and Cg-X expressed its strong support for all efforts to find solutions. The latter called for international and interdisciplinary efforts, and Congress saw the need for flexibility in WMO's activities in this field so as to permit the Organization to make as great a contribution as it could to the efforts required. Congress also saw the need for an interdisciplinary and hence interagency approach to the solution of many water-related problems. It therefore welcomed and endorsed WMO's continued efforts to contribute to interagency projects designed to alleviate such problems. Congress was pleased to note the co-operation between WMO and Unesco in many projects, including those of WCP-Water. It also welcomed the close link maintained with the International Association of Hydrological Sciences (IAHS). Co-operation with these and other international organizations in water-related activities was seen by Congress as avoiding duplication and permitting a more rational use of funds allocated by each of the organizations to activities requested by Members.

2.8 By its Resolution 9 (Cg-X) on global climate change, Congress recognized that national and international studies have led to the conclusion that a global climate change will ensue from increases in the concentrations of greenhouse gases and that this climate change could have potentially serious consequences on society. It agreed that WMO, through the WCP, has a responsibility to provide members with state-of-the art projections of long-term changes in the global climate.

2.9 The WMO Executive Council expressed its satisfaction that the scientific advances made in several aspects of the WCRP and its appreciation of the role played by the WMO/ICSU Joint Scientific Committee (JSC) in providing scientific guidance for the conduct of the programme. The International Biosphere-Geosphere Programme (IGBP), being implemented under the auspices of ICSU, was seen as being very important in this regard. A call was made for a strengthening of co-operation between the WCRP and IGBP so as to ensure the complementarity of their studies of climate change issues and of global change. The IGBP Working Group on Data and Information Systems will examine the observational requirements for the study of global change, with due consideration to existing data bases provided by WMO.

#### The Eighth Session of the Intergovernmental Council of the International Hydrological Programme

2.10 The Eighth session of the Council took place in Paris from 21 to 25 June 1988.

2.11 The Council reviewed the progress of the activities within the third phase of the IHP (1984-1989) which included those IHP projects which are part of WCP-Water. The Council expressed its satisfaction with the results obtained so far.

2.12 The Council at this session also determined the Outline Plan for IHP-VI (1990-1995). This phase of the IHP has been given the title "Hydrology and Water Resources for Sustainable Development in a Changing Environment". A major emphasis will thus be on activities concerning the relation between hydrology and water resources and climate variability and change. In particular an effort will be made to improve the scientific hydrological methodologies necessary to be able to predict consequences of possible climate change on the hydrological cycle.

#### Objectives of the World Climate Programme

2.13 The overall objectives of the WCP are:

- (a) To apply existing climate information to the benefit of mankind;
- (b) To improve understanding of climate processes so as to accelerate:
  - Determination of the predictability of climate;
  - Development of long-range weather forecasting;
  - Determination of the extent of man's influence on climate;

- (c) To monitor significant climate variations or changes, either natural or man-made, and to develop the capability to warn Governments of impact which could markedly affect economic and social activities of mankind.

#### World Climate Data-Programme

2.14 The purpose of the World Climate Data Programme (WCDP) is to ensure timely access to reliable climate data which are exchangeable in an acceptable format to support climate applications, impact studies and research. The scope of the WCDP includes data from the entire climate system, being composed of the atmosphere, oceans, cryosphere and land surface (including the biosphere).

2.15 To improve the timely availability of climate data and information, the long-term objectives of the WCDP are:

- (a) To assist countries in improving their systems for climate data management, primarily through a transfer of technology, with emphasis on the use of WWW facilities and microcomputer systems;
- (b) To consolidate requirements for climate data observations and exchange, and for the co-ordination of existing data-exchange systems;
- (c) To improve the availability of referral information on climate data sets, station networks and publications;
- (d) To assist countries and WMO Regions to build climate data banks (including data from Reference Climatological Stations) for applications, impact studies and research;
- (e) To develop a system to monitor, diagnose and disseminate information on significant climatic events which may affect mankind's activities, using existing capabilities.

#### World Climate Applications-Programme

2.16 The purpose of the World Climate Applications Programme (WCAP) is to promote applications of existing climate knowledge. Within its scope lies a wide range of climate applications in nearly all human activities. The priority areas are food, water and energy but applications in other areas such as urban and building climatology and climate and human health will be undertaken as resources permit. Nations can benefit greatly from improved use of climate information in planning expensive national projects such as major water-resource systems, new agricultural lands, urban renewal, and wind or solar-energy systems. The benefit-to-cost ratio of good climate applications is nearly always greater than 2:1 and often exceeds 10:1.



2.17 The main long term objectives of the WCAP are:

- (a) To help Members to strengthen their national institutional capabilities to apply climate knowledge;
- (b) To make available existing basic knowledge about the climate of each region, presented in a way to permit ready application, in a user-tailored form;
- (c) To provide ready access to practical techniques for application of climate knowledge;
- (d) To promote the development, transfer of knowledge and use of climate application techniques through:
  - Increasing the awareness of users on the potential benefits to be gained through the application of climate knowledge;
  - Defining requirements for climate information by specific users;
  - Provision of guidance material and training.

#### World Climate Impact-Studies-Programme

2.18 The purpose of the World Climate Impact Studies Programme (WCIP) is to introduce climate considerations into rational policy alternatives and warn of the economic and social impacts of climate variations and changes, both natural and man-made. Priority areas include the assessment of the social, economic and political consequences of climate change induced by carbon dioxide and other greenhouse gases; reduction of the vulnerability of food systems to climate; development and application of methods for climate impact assessment; and the assessment of the impact of climate variability and change in climatically sensitive sectors of the human environment. The extent to which this can be accomplished may be limited by available resources.

2.19 The main long-term objectives of the WCIP are:

- (a) To improve knowledge of the impact of climate variability and change in terms of the specific primary responses of natural and human systems;
- (b) To develop knowledge and awareness of the interactive relations between climatic variability and change and human socioeconomic activities;
- (c) To improve the methodology so as to deepen understanding and improve the simulation of the interactions among climatic, environmental and socioeconomic factors;
- (d) To determine the characteristics which make human societies at different levels of development and in different natural environments especially vulnerable or especially resilient to climatic variability and change.

### World Climate Research-Programme

2.20 The purpose of the World Climate Research Programme (WCRP) is to improve our knowledge of climate, climatic variations and the mechanisms which bring about climate change so as to be able to determine to what extent climate can be predicted and the extent of man's influence on climate. This research programme encompasses studies of the global atmosphere, oceans, sea and land ice and land surface which constitute the Earth's climate system.

2.21 In order to achieve this purpose, the programme must meet the following long-term objectives:

- (a) To improve and expand knowledge of the characteristics of global and regional climates, including their temporal variations and significant trends;
- (b) To design and implement observational and theoretical research programmes that will lead to a better understanding of significant climate processes, including the exchange of heat and momentum between atmosphere and ocean; the interaction between cloudiness and radiation; and the mutual influences of climate and land-surface characteristics;
- (c) To develop models capable of simulating the climate system in order to develop and demonstrate, to the extent possible, capabilities for climate prediction on a wide range of space and time scales;
- (d) To determine the sensitivity of climate to possible natural and man-made influences such as the increasing concentrations of CO<sub>2</sub> and other radiatively active species in the atmosphere.

### 3. GENERAL REVIEW OF CURRENT AND PLANNED ACTIVITIES

#### World Climate Data Programme

3.1 The meeting was informed that projects being implemented under the WCDP continued to assist members in improving the capabilities of national Services to efficiently manage their climate data through:

- the exchange of CLIMAT reports at Regional and World Meteorological Centres;
- the CLICOM project which is directed to addressing the basic needs of Services by providing computer systems, software and training to carry out more efficiently climate data management and user service functions;
- the development of INFOCLIMA, a catalogue of climate system data sets aimed at the distribution of information on station inventories and histories and climate data sets;
- Climate System Monitoring (CSM), incorporating coverage of issues related to climate change problems.

#### World Climate Applications Programme

3.2 The meeting noted the importance of the work on defining the user requirements and potential economic and social benefits in various sectors of climate applications under the WCAP. Further information and guidance on these matters, including guidance on how to use information on regional features of climate change, will assist meteorological and hydrological services to maximize the impact of their services on national economic and social development. The WMO Executive Council, on its Fortieth Session in June 1988, stressed the importance of further studies of the sensitivity of water resources to climate and its variability and change. The need was recognized for continued close co-ordination of the various projects within WCAP-Water with other international organizations. In the light of the growing problems in drought stricken areas, the Council stressed very strongly the need for continuing emphasis on studies and development of climate applications for these areas. It was noted that the development of techniques for drought risk/probability mapping should be of great value to the members as will the guidelines on the use of climate information to mitigate effects of droughts.

### World Climate Impact Studies Programme

3.3 Particular priority under the WCIP (UNEP) is being given to the greenhouse gas/climate change issue. This is being done by improving public information on the issue; encouraging dialogue on climate change among the scientific, technical and decision-making communities; assessing regional vulnerability to sea level rise; undertaking regional analyses of the impacts of climate change and the consideration of various response options; and at the request of the governing council of UNEP, identifying the full range of policy options which governments and international organizations might consider for responding to climate change.

### World Climate Research Programme

3.4 The concept of the Global Energy and Water Cycle Experiment (GEWEX) was prepared by a JSC Study Group, with the main objectives being:

- To determine the hydrological cycle and energy fluxes by means of global measurements of observable atmospheric and surface properties;
- To model the global hydrological cycle and its impact in the atmosphere and the ocean;
- To develop the ability to predict the variations of global and regional hydrological processes and water resources, and their response to environmental change;
- To foster the development of observing techniques, data management and assimilation systems suitable for operational application to long-range weather forecasts, hydrology and climate predictions.

3.5 GEWEX is seen as an essential step in the study of long-term climatic variations and global climatic change and as having important implications not only for other WCRP activities, but also for the future planning of WCP-Water. Other activities under the framework of WCRP are carried out by the Unesco Intergovernmental Oceanographic Commission (IOC), ICSU and its Scientific Committee on Oceanic Research (SCOR) and by WMO through the World Ocean Circulation Experiment (WOCE), which is seen as vital to an understanding of the crucial role of the ocean circulation in determining global climate change on all time scales beyond the seasonal cycle.

### The Intergovernmental Panel on Climate Change

3.6 The WMO Executive Council has agreed in its Fortieth Session that, as a response to the recommendations made by the Workshop on Developing Policies for Responding to Climatic Change (Bellagio, 9-13 November 1987) supported by the Advisory Group on Greenhouse Gases (AGGG), WMO should undertake a study of what new climate observing system activities are required for monitoring the changing climate. The Council stressed that such a study should cover monitoring of all physical aspects of climate change. To carry out internationally coordinated scientific assessments of the magnitude, timing and potential impact of climate change, the EC adopted its Resolution 4 (EC-XL) by which the Intergovernmental Panel on Climate Change (IPCC) has been established and will report to the governing bodies of WMO and UNEP.

3.7 The activities of IPCC are aimed at:

- (i) assessing the scientific information that is related to the various components of the climate change issue, such as emission of major greenhouse gases and modification of the Earth's radiation balance as a result, and that needed to enable the environmental and socioeconomic consequences of climate change to be evaluated;
- (ii) formulating realistic response strategies for the management of the climate change issue.

3.8 The IPCC will incorporate in an overall plan for its activities the need for:

- (a) Identification of uncertainties and gaps in our present knowledge with regard to climate change and its potential impacts;
- (b) Identification of information needed to evaluate policy implications of climate change and response strategies;
- (c) Review of current and planned national/international policies related to the greenhouse gas issue;
- (d) Scientific and environmental assessment of all aspects of the greenhouse gas issue and the transfer of these assessments and other relevant information to governments and inter-governmental organizations to be taken into account in their policies on social and economic development and environmental programmes.

#### Operational Hydrology and WCP-Water

3.9 The main aim of contributions by the WMO Commission for Hydrology to WCP-Water is to ensure an effective input from operational hydrology to water-related aspects of studies of climate and the use of climate information for water-resource activities. The objectives are concerned with the effective use of climate data and information in the planning and operation of water-resource systems and with the use of hydrological data in climate-related studies.

3.10 The eighth session of the Commission for Hydrology (CHy-VIII) will be held in October/November 1988 in Geneva. It has been decided to convene a Technical Conference on the Hydrology of Disasters during CHY-VIII. The conference can serve as the first organized contribution by WMO to the International Decade for Natural Disaster Reduction (IDNDR) that has recently been designated by the United Nations.

3.11 The priorities and plans for the future structure of the Commission, having taken into account the Second WMO Long-term Plan, the recommendations of the Third Unesco/WMO International Conference on Hydrology and the views expressed by the Tenth Congress, encourage CHy to increase its activities at the interfaces between operational hydrology on the one hand, and meteorology, water management, climate studies and, in particular, environmental management on the other, while at the same time maintaining its role in the development of operational hydrology.

3.12 The future priorities of the CHy activities are likely to be in the following fields:

- (a) Systematic development of the various components of operational hydrology;
- (b) Development of national Hydrological Services, in particular in the application of up-to-date techniques;
- (c) Evaluation of the influence of man on the environment, in particular with respect to water quantity and quality;
- (d) Hydrological aspects of natural and man-made disasters.

#### WMO Regional Associations

3.13 Many of WMO's activities are undertaken on a regional basis and are conducted under the auspices of one or other of the Organization's regional associations, namely:

Regional Association I	(Africa)
Regional Association II	(Asia)
Regional Association III	(South America)
Regional Association IV	(North and Central America)
Regional Association V	(South-west Pacific)
Regional Association VI	(Europe).

3.14 Each of these associations has established a working group on hydrology with various terms of reference. At the request of Congress the associations pay particular attention to regional aspects of WCP and, consequently, the associations have appointed various members of their working groups on hydrology to undertake specific tasks in relation to WCP-Water. The implementation of these tasks is closely coordinated with the overall global activities under WCP-Water.

#### Unesco Medium-Term Plan

3.15 The Executive Board of Unesco at its 129th and 130th sessions in 1988 laid the groundwork for Unesco's future Medium-Term Plan (1990-1995) to be adopted by the 25th General Conference in 1989.

3.16 One of the major programme areas in the future Medium-Term Plan will be "Science for Progress and the Environment". Within this programme area a large place will be held by environment and natural resources management for sustainable development in a situation of global change. The global change aspect includes possible changes in climate. The objectives of the related activities are preliminarily formulated as follows:

"Contribution to the gradual establishment, under the main programmes on environmental protection and natural resources management for sustainable development, of networks for research, dissemination of data and monitoring of the changes in and risks threatening the global environment (in conjunction with the global change programme of the International Council of Scientific Unions (ICSU), the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), etc.); preparation of studies, models and scenarios concerning the impact of global changes on societies."

### Unesco International Hydrological Programme

3.17 In the outline plan for the fourth phase of the IHP (1990-1995) themes and projects relevant to WCP-Water are under the sub-programme: Hydrological research in a changing environment.

3.18 The aim of this sub-programme is the adaptation of the hydrologic sciences to be able to cope with the expected changing climate and environmental conditions, which have become more obvious since the inception of the programme. The objectives have been formulated as follows:

- (i) To improve knowledge of the processes involved in the hydrological cycle and to determine the manner in which these processes might be most appropriately described to meet the demands for planning, design, construction, maintenance and operation of water management schemes within changing climatic and environmental situations;
- (ii) To provide, in co-operation with the international scientific community ' a general framework for the national, regional and international development of hydrology and the related water sciences.

3.19 The most relevant themes and planned projects are:

Theme H-1: Interface processes between atmosphere, land and water systems

- Project H-1-1: Review of the scientific aspects of the interface processes of water transport through the atmosphere-vegetation-soil system at an elementary catchment and grid size scale
- Project H-1-2: Study of erosion, river bed deformation and sediment transport in river basins as related to natural and man-made changes.

Theme H-2: Relationship between climate variability (and expected change) and hydrologic systems

- Project H-2-1: Study of the relationship between climate variability (and its expected change) and hydrologic regimes
- Project H-2-2: Hydrology, water management and hazard reduction in low lying coastal regions and deltaic areas in particular with regard to sea level changes
- Project H-2-3: Extraordinary rainfall and snowmelt floods in rivers of the world.

### United Nations Environment Programme

3.20 It was decided by the Advisory Working Group on Water Resources Programme of UNEP that research should be conducted especially on the possible shift of the climate belts and the effect of this on the pattern of water use, i.e. how to take climate change into consideration in design criteria for water management systems. It was recommended that research topics should be carefully selected to ensure they produce useful results which could be directly applicable.

3.21 UNEP's intellectual contribution to the ICSU's International Geosphere-Biosphere Programme (IGBP) will be to provide recommendations in all relevant fields.

3.22 It should be emphasized that the overall objective for the IGBP is much broader than the problems related to fresh water systems. Similarly, UNEP's interest in WCP and in the IGBP is also broad. This is evident from Annex 3, which lists the on-going and planned activities of UNEP relating to climate.

3.23 Besides the specialized project on the global climate change related to IGBP, UNEP is also concerned with the climate change impacts on water resources development. Under its Programme for the Environmental Sound Management of Inland Waters (EMINWA), attention is paid to the environmental aspects of the development of river basins. At present, Lake Chad and its deterioration is the major matter of concern. All possible causes of the lake's degradation are being analyzed and all plausible water supply alternatives for the basin under short, medium and long-term climate change impacts are being considered. The results will be presented to the Lake Chad Basin Commission early in 1989.

3.24 Similar types of project are in preparation for Latin America and Asia.

### FAO

3.25 FAO has now taken several initiatives to intensify activities concerned with climate issues, including possible climate change. While all these initiatives are in the field of agriculture, forestry and fisheries, a number of them, particularly those related to agriculture are heavily involved with water aspects of the agricultural production, such as irrigated crops. In addition to the FAO project already included in WCP-Water (Project C.3 on the water potential for irrigation in Africa), two other FAO projects can now be included in WCP-Water, namely one on sensitivity to climate change (greenhouse effect) of irrigation water availability, including reservoirs, and a second on population support capacity of land, based on agro-ecological zones established according to climatic, among other characteristics. FAO therefore looks forward to increased co-operation with WCP in general and WCP-Water in particular.



An International Geosphere-Biosphere Programme: A study of global change (IGBP)

3.26 In September 1986, the ICSU General Assembly in Berne (Switzerland) decided to establish the International Geosphere-Biosphere Programme: A study of global change (IGBP).

3.27 The ICSU Executive Board set up a Special Committee for the IGBP (SC-IGBP). The first meeting on the SC-@LGBP took place in Paris in July 1987. It agreed to accept the objectives for the IGBP as proposed by the ad hoc Planning Group, namely:

"To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions."

The first meeting also decided on four underlying themes, which were considered vital to the development of IGBP:

- (a) Documenting and predicting global change;
- (b) Observing and improving our understanding of dominant forcing functions;
- (c) Improving our understanding of transient phenomena in the total Earth system;
- (d) Assessing the effects of global change that would cause large scale and important modifications affecting the availability of renewable and non-renewable resources.

3.28 It was decided to start the planning for a research programme on four topics, for each of which Co-ordinating Panels were set up:

- (a) Terrestrial Biosphere-Atmosphere Chemistry Interactions;
- (b) Marine Biosphere-Atmosphere Interactions;
- (c) Biosphere Aspects of the Hydrological Cycle;
- (d) Effects of Climate Change on Terrestrial Ecosystems.

The following working groups were established to assess the current state of knowledge and future prospects:

- (a) Global Geosphere-Biosphere Modelling;
- (b) Data and Information Systems;
- (c) Techniques for Extracting Environmental Data of the Past;
- (d) Geosphere-Biosphere Observatories.

3.29 A central focus of the IGBP is the biospheric regulation of the total Earth system and how this affects the chemistry of the atmosphere and the biogeochemical cycles, including the hydrological cycle, and how they interact with the physical climate system.

3.30 The scope of the Panel on Biospheric Aspects of the Hydrological Cycle is of particular interest to the WCP-Water. This panel identified as a main goal for the IGBP to better understand the role of vegetation in the hydrological cycle for the purpose of modelling its linkage to global climate change. In order to understand the dynamics of and the synergism among soils, vegetation and atmosphere on the small scale and their integrated effects on the macro or grid scale there is an urgent need to:

- study the regional distribution of energy, moisture and momentum sinks and sources over the land surface and their seasonal variability, especially the role of the biosphere in controlling these fluxes at various scales;
- - explore by experiments and models whether our understanding of the hydrological processes involving vegetation on the small scale can be rigorously integrated over space to describe interactions appropriate to scales of global models, and
- verify the usefulness of remote sensing for quantifying processes and integration across scales.

3.31 It had been recommended that IGBP, together with other relevant bodies, plan for an integrated and coordinated cross-disciplinary research programme. The programme must include aspects of the hydrological basin system, water pathways in the ground, vegetation and soil properties, planetary boundary layer problems as well as monitoring and archiving of changes.

3.32 A hierarchy of models was expected to be developed and improved based on physical processes and generating or requiring observable data on a global scale to study the interaction of different processes in the soil-vegetation atmosphere system:

- models of large river basin systems and grid networks;
- higher resolution models of watersheds or regional systems, including more knowledge about the different processes. The models are needed to evaluate remote sensing data or experimental results;
- process-related models for the most important processes governing the interaction between the components of the soil-vegetation-atmosphere system.

3.33 To study the general problems identified above requires an integrated programme of research work that combines satellite observations with carefully selected experimental work that has to be done on the "ground". To facilitate the interpretation of satellite data and to test the hydrological models three types of experiments will be performed:

- (a) Single-parameter experiments on a small scale;
- (b) Complex experiments of pixel array scale;
- (c) Grid-scale experiments.

A concept of monitoring and of an observatory system in accordance with the geosphere-biosphere observatory network was developed. Such an observatory system is essential to the investigation of changes of biosphere hydrological cycle interactions.

#### Development of WCP-Water projects

3.34 The meeting recalled that the World Climate Programme was both inter-disciplinary and inter-agency in nature. While WMO and Unesco took joint responsibility for convening meetings to plan WCP-Water activities, there was no intention for the two organizations to be separately or jointly responsible for each of the WCP-Water projects. The meeting therefore welcomed the information provided by the representatives of other agencies and programmes as to their planned activities. It was noted that the flexible project structure that had been adopted for WCP-Water planning permitted the inclusion of any relevant international or national project. The current plan already contained projects initiated and implemented by FAO, IAHS, Czechoslovakia, Switzerland, UK and USA.

3.35 The plans for IGBP and those of UNEP referred to under 3.13 to 3.25 above were seen as being very relevant to WCP-Water. The meeting therefore expressed the hope that relevant projects would soon be identified by LTNEP and by ICSU for inclusion in the overall plan for WCP-Water.

#### Helsinki Conference

3.36 A Conference on Climate and Water is being convened by WMO and will be held in Helsinki, Finland, from 11 to 15 September 1989 with the co-sponsorship of Unesco, UNEP and IAHS. It should provide an excellent forum for the discussion of the potential impact of climate change on water resources and will contribute directly to the Second World Climate Conference. The aim of the conference is to bring together experts involved in projects concerned with climatic variability and change and the impact on hydrology and water resources.

3.37 The improved understanding of the interrelationship between climate and water should provide a better basis for developing plans to eliminate the negative impact of climatic change on water resources.

The Second World Climate Conference

3.38 The Second World Climate Conference will be held immediately after the forty-second session of the WMO Executive Council in June 1990. The purposes of the conference will be:

- (i) To create an awareness, through specific case studies or examples drawn from experience in the World Climate Programme, of the economic impact of the climate and benefits from climate applications;
- (ii) To assess the current state of knowledge on the global issues of climate change and greenhouse gases (GHG's), requirements for scientific activity and implications for public policy.

3.39 The theme title of the conference will be "Climate Change and the Modern World". The arrangements for the convening of the conference are to be made in co-operation with UNEP, ICSU and other international agencies.

#### 4. IMPLEMENTATION OF WCP-WATER PROJECTS UNDER THE SIX ACTIVITY AREAS

The meeting considered each of the current WCP-Water projects in some detail. It recorded its views and recommendations in the following paragraphs of the report. It also prepared up-dated and revised projects sheets for each project, taking account of these recommendations. These are presented in Annex 4.

##### A. Studies of hydrological data in the context of climate variability and change

###### A.1 Analyzing historical hydrological and related information -----

A.1.1 The meeting considered the past activities and the progress made in the project implementation and discussed in detail the type of data and information of concern to the project. The main feature of the historical information collected and processed under the Project A.1 was felt to be the non-systematic nature of these data as compared to the instrumentally recorded time-series dealt with under Project A.2.

A.1.2 It was proposed to slightly change the project title so as to account for the very broad applicability of the project results.

###### A.2 Analyzing long time series of hydrological data and indices -----

with respect to climate variability and change  
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A.2.1 The meeting noted with satisfaction the progress achieved under this project and discussed in detail the future actions to be undertaken to ensure its further implementation. It was considered that the main future activity should be the application of the methodology that have been prepared and the analysis of the large number of time series which it was hoped would be supplied by member countries. In this respect, it will be necessary to process the results of these analyses and to draw all necessary conclusions before the next phases of the project can be planned in any detail.

A.2.2 Following recent findings in climate research, it was proposed to change the project title so as to include a reference to climate change as well as to climate variability.

A.2.3 Note was taken of the importance of establishing a fixed period in time to be used in comparative areal studies of variability.

A-3 Distinguishing between the influence of man's activity

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and climate variability on the hydrological cycle  
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A.3.1 The meeting noticed the progress of the IHP rapporteurs on IHP-III project 6.3 in the preparation of a methodology for distinguishing between man's influence and climate variability effects. A first draft had been presented as a paper to the Vancouver symposium. The final version, however, will differ substantially from the draft presented in Vancouver.

A.3.2 The final version of the report will be presented at the Conference on Climate and Water in Helsinki in 1989.

A.4 Monitoring of glacier fluctuations

A.4.1 The meeting was informed of the success in the implementation of this project, which is continuing according to the original plans, and the support received from UNEP for this project.

A.4.2 The project is implemented by the combined secretariats of the World Glacier Inventory and the Permanent Service on the Fluctuations of Glaciers housed at the ETH in Zurich, Switzerland.

A.5 Collection of global runoff data sets

A.5.1 Mr. Liebscher reported on progress with the development of the WMO Global Runoff Data Centre (GRDC). It was noted that the Institute-for Bioclimatology and applied Meteorology of the University of Munich had acted as the GRDC from 1983 to 1987 and that on 1 May 1987 a permanent GRDC had been set up in the Bundesanstalt für Gewässerlimde in Koblenz, Federal Republic of Germany (FRG). All data had now been transferred from Munich to Koblenz.

A.5.2 The meeting was pleased to learn that a link had already been established between the GRDC and the Global Precipitation Climatology Centre (GPCC) located at Offenbach, FRG. It was proposed that links also be extended to FAO, with regard to its data bases on soils, groundwater and precipitation, and to UNEP, with regard to its GRID system, currently based in Geneva and Nairobi.

A.5.3 The GRDC already contained the data published by Unesco in "Discharges of selected rivers of the world". In view of the current plans of Unesco to collect additional data of this nature, in particular from Africa, it was proposed that contact be maintained with Unesco so as to ensure the maximum input of information to the GRDC.

A.5.4 The meeting was informed of the workshop on the Global Runoff Data Set and Grid Estimation which was scheduled to held in Koblenz from 10 to 15 November 1988 and was pleased to note that this was expected to define in quite concrete terms the role and means of operation of the GRDC.

A.6 Transfer of hydrological information to grid point or average grid area values  
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A.6.1 The meeting recognized the particular importance for Project A.5 of developing a technique or techniques for transferring the available hydrological information to grid point or grid area values for use by AGCM'S. This was the reason Why Project A.6 had been identified as a separate entity from Project B.3 and listed under activity area A. It was noted that useful work had been undertaken under Project A.6.

A.6.2 As recorded above, the GRDC was now well established in Koblenz and transfer techniques would have to be tested and applied in the near future. It was recognized, however, that Project B.3 was also concerned with such techniques, although in a wider context. It was therefore felt that it would be preferable now to incorporate Project A.6 as a specific sub-project of Project B.3.

A.7 Global Energy Balance Archive (GEBA)  
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A.7.1 The meeting noted the excellent progress that had been made in the establishment of the archive as described by Mr. Gilgen. The data base management system was explained, together with the sources of the data and the quality control procedures, the latter being based in part on checks against given, ranges of physically possible" values.

A.7.2 Plans for the coming few years included linking the system to on-line international networks and the provision of a "self-service" facility for those who wish to view and use the data. Studies of the time series of radiation data were foreseen for the near future. Data collection and input was established as a routine on-going activity.

A.7.3 The meeting recognized the value of maintaining close contact with the World Radiation Data Centre in Leningrad and encouraged the strengthening of the link already established.

B. Modelling of the hydrological cycle

B.1 Coupling of physically based climate and hydrological models  
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B.1.1 The original formulation of this project emphasized the importance of bringing together those who work on physical climate models and those expert in hydrological modelling. This aim was still seen as being very valid. A number of modelling techniques were known to have been developed in recent years which could aid in coupling the two types of models and it was felt that work on such techniques should be included under the heading of this project.

B.1.2 In view of the above, it was proposed that Project B.2 be incorporated in Project B.1 and that specific encouragement be given to national institutes, either as individual or joint initiatives, to develop and test techniques for coupling climate and hydrological models.

B.1.3 Activities in this regard were expected to develop over the next few years. It was recommended that a technical scientific meeting or series of meetings be convened in due course to bring together those concerned with the subject. Links will need to be established with the IGBP.

B.2 Development and application of second generation grid-orientated hydrological  
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modelling techniques  
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For the reasons given under B.1 above, it was proposed that Project B.2 be incorporated in Project B.1.

B.3 Development of grid-related estimates of hydrological variables  
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B.3.1 The meeting noted the plans of WMO for the preparation of a report on the state of the art of grid-point and grid-area estimation of hydrological variables. A draft of this report was to be considered at the Workshop on the Global Data Set and Grid Estimation (Koblenz, November 1988). It was anticipated that both the final report and the discussion at the Koblenz Workshop would make valuable contributions to the implementation and to the further planning of this project.

B.3.2 It was felt that before techniques of grid-point and grid-area estimation were widely endorsed, they should be tested, as currently proposed under Project B.3. This will be particularly important if the techniques are to be used in any studies involving the prediction of future states. Good data sets will be required for these proposes. Those being compiled in relation to Project B.4 may be of value in this regard.

B.4 Hydrological aspects of HAPEX  
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B.4.1 The meeting noted with interest the progress that had been made in the implementation of HAPEX. It was recognized that this depended on individual countries, or groups of countries, undertaking substantial data collection experiments. Three of such experiments had been substantially completed and a series of further experiments were in various stages of planning.

B.4.2 The data provided by these experiments were seen as being of very great potential value to WCP-Water projects. However, from the information available to the meeting, it was unclear as to whether the nature of the hydrological data provided by the HAPEX-MOBILHY and FIFE experiments was such as to allow them to be used in WCP-Water projects such as Project B.1 and B.3. The hope was expressed that future HAPEX activities, such as the Storm Central experiment, would yield data sets which would be of direct use to hydrologists.



B.4.3 It was suggested that further experiments might be undertaken, either by one country or by a number of neighboring countries, to compile data for use in studies of linking climate and hydrological models. The emphasis of such a project would be on monitoring the components of the hydrological cycle as seen from the point of view of the hydrologist. WMO may be able to assist by supporting the necessary planning meeting.

B.4.4 Mention was made of the Elbe basin as one possible location for such an experiment, based on co-operation between the relevant institutes of the German Democratic Republic and Czechoslovakia.

B.4.5 The clarification of the scope of Project B.1 led the meeting to question the current title of Project B.4. It was proposed to remove the reference to "modelling" and to refer simply to the "Hydrological aspects of HAPEX".

B.5 Use of atmospheric moisture transport information for water balance computations  
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B.5.1 The meeting was informed on the progress with IHP-III Project 1.1 "Preparation of a technical report and case studies on the use of data on atmospheric moisture transport over continents and large river basins for the estimation of water balances and other purposes".

B.5.2 In view of the possible use of aerological methods for linking surface hydrological-and climatic knowledge in the framework of climate change studies, the planning group decided to establish a new project identified as B.5 with the title given above.

C. Application of climate information in the Planning design and operation of water-resources systems

C.1 Application of climatological data and methods to water-resources project  
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Consideration was given to a proposal that the technical report/guide be aimed at a more advanced market in view of the ready availability of basic material on the application of climate data. The meeting's attention was drawn to IHP Project 3.1 (see WCP-Water Project D.2) for which a source book on a related topic was already in preparation. In view of the rapidly changing scene in climatology and the existence of the IHP Project, it was recommended that material continue to be accumulated but action be delayed on the preparation by WMO of a report/guide until the matter has been considered by the WMO Commission for Hydrology at its eighth session (Geneva, October/November 1988).

C.2 Application of climate information for water projects in the Sahel  
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C.2.1 The meeting was informed of the various activities-that had been implemented in conjunction with this project, noting that the last of these was a technical meeting on hydrological design criteria held in Dakar in 1986.

C.2.2 Further action under the project was seen as being very much dependent on relevant technical co-operation and similar activities in the Sahel region. In the last two years these activities had not been concerned so much with hydrological matters and so work under the project had not developed as much as in the past.

C.3 Application of climate information to irrigation water supply assessments in  
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Africa using a digital geographic information system data base  
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The meeting welcomed the information on progress with the project provided by the FAO representative and noted the plans for its future implementation. The second phase of the project was seen as concentrating on a more detailed assessment which will be prepared for selected basins of the Africa continent.

C.4 Application of conditional climatological information to water supply forecasting in the U.S.A.

C.4.1 The meeting was informed by a document submitted by the US National Weather Service as to the current status of this project. It was seen as progressing according to schedule.

C.4.2 Interest was expressed in a number of aspects of the project and the US National Weather Service was encouraged to continue with the work it was undertaking.

C.4.3 As on previous occasions, the term "positional" caused some discussion. It was proposed that, in the title only, the word be replaced by "conditional" so that the subject of the project be more easily understood in any simple listing of WCP-Water projects. The term "positional" would be retained in the project description (see Annex 4) together with the footnote explaining its precise meaning.

C.5 Re-analysis of hydrological observations in Czechoslovakia  
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The meeting was informed by Mr. Hladny of the current stage of implementation of the project and the activities planned for the future. Here, as under Project A.2, the meeting recognized and discussed the value of unifying reference periods which could enable a comparison of the results from various analyses. It was suggested that the question of reference periods be discussed further in a wider context with the aim of achieving some agreement in this respect.

C.6 Teleconnexion of the El Niño phenomenon with extreme hydrological events in South America  
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C.6.1 The meeting was informed that WMO Regional Association III (South America) had included among its activities the task of assisting in water-related activities in the region under WCP-Water.

C.6.2 The Association had appointed a rapporteur on the hydrological aspects of the El Niño phenomenon as a member of its Working Group on Hydrology. The rapporteur had prepared a work plan in which the proposals for future implementation had been outlined. Material was being collected and collaboration had been offered by experts from South America and the U.S.A. who were working on this subject. Progress would be reported at the meeting of the working groups scheduled for 1989.

D. Studies of the influence of climate change and variation on water resources

D.1 Sensitivity of water-resource systems to climate variability and change  
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D.1.1. The title was modified to reflect the broader concern of Project D.1 with CO<sub>2</sub> induced climate change and to conform with the pattern adopted in other projects, e.g. A.2 and D.3.

D.1.2 The meeting took special note of the results of the Norwich Workshop (November 1987) :

- (a) compilation of global data sets and bench-mark time series (A-1, A.2 and A.5)
- (b) testing suitability of models for climate impact studies (D.1, output b and D.5)
- (c) documentation of societal and water-resource response to past episodes of change, e.g. drought (D.1, output d)
- (d) scenario development and modelling of the water-resource response (D.1, output c)
- (e) role of the biosphere on the water balance and of CO<sub>2</sub> enrichment on plant water relations (D.1, output b and IGBP)
- (f) development of grid scale land surface process models including feedbacks to atmosphere (B)
- (g) study of the role of storage mechanisms on time series structure of hydrological data (D.1, output b and D.5)
- (h) further studies of chemical pathways and geophysical processes in relation to hydrology and water in the 14.4-biosphere (IGBP and WCRP).

Links with WCP-Water activities are noted in the above list. The meeting also urged the explicit inclusion of water quality impact through temperature effects.

D.1.3 Discussion ensued on the following policy checklist:

- a) A search for evidence of non-stationarity in regional climate and hydrological data sets
- b) Demonstration of the degree of resistance to hypothetical changes to input hydrological series perhaps constructed from the more disadvantageous periods from within the historic record
- c) A review of the overall performance of the project against more general criteria including environmental and social impacts within the existing climate regime
- d) Consideration of the sensitivity of components of the project to first order effects of climate change, i.e. higher temperature, reduced snow-pack, glacier runoff, higher sea levels
- e) Informal inspection of AGCM-based scenarios for 2 x CO<sub>2</sub> anomalies and evaluation of project design criteria if rainfall and temperature time series were adjusted to accord with the revised mean values.

The cautious tone was welcomed, as was the idea that it was now timely for policy issues to be raised given the increasing certainty of a greenhouse effect on water resources.

D.2 Use of climate data for the study, planning and management of water resources  
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D.2.1 The meeting expressed its satisfaction with the success of the IAHS 1987 Vancouver Symposium on the Influence of Climate Changes and Climatic Variability on the Hydrological Regime and Water Resources, supported by Unesco and WMO. This Symposium provided a compilation of existing information on the relative vulnerability of different water-resource systems to climate variability and change.

D.2.2 The planning group was also informed about the progress with the preparation of the source book on climatology for hydrologists and water engineers (IHP-III Project 3.1). A sub-group established during the meeting discussed the existing parts of the drafts and decided on the finalization of the book. It is expected to be completed by the end of 1989 and will be published by Unesco.

D.3 Study of the impact of climatic variability and change in the occurrence of droughts  
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The meeting was informed that the Unesco/IHP rapporteur expects to complete his report on the subject in 1989.

D-4 Study of the impact of climate variability and change in the occurrence of floods in urban areas  
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D.4.1. The planning group noted that no specific activities were undertaken under this leading. It was informed that the impact of possible climate change on urban floods is listed as-a priority area in the United Kingdom.

D.5 Testing the transferability of hydrological simulation models  
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D.5.1. The meeting reaffirmed the importance of assessing the validity of any techniques used to predict the possible impact of climate change, including the testing of hydrological models for this purpose. The procedure proposed by Mr. Klemes in WCP Report N° 98 may not be the only option, but it was certainly one to be considered seriously.

D.5.2 The meeting was pleased to learn from Mr. Refsgaard of plans of the Danish Hydraulic Institute to apply Mr. Klemes' procedure to three models of different complexity that they use.

D.5.3 During a more wide-ranging discussion, reference was made to the need to bear in mind the errors inherent in data and in climate scenarios when assessing the performance of individual models. It was also suggested that, if hydrological models are to be useful for studies of climate change impact, their future development should be based on inter-disciplinary work, particularly as regards vegetation and its interaction with the climatic environment.

D.6 Impact of CO<sub>2</sub> induced climate change on UK water-resources

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D.6.1 The meeting welcomed the progress report on Project D.6 presented by Mr. Beran which referred also to investigations in Africa and Europe. Scenarios had been developed for climate change from AGCMs and other sources for testing the sensitivity of UK water supply reservoirs. In Africa a desk study had been completed for FAO which had indicated major reductions in reliability of irrigation possibilities using a reservoir. "Signal detection" and "fingerprint" studies of European flood series were also presented.

E. Impact of climate on society through water resources

It was recalled that this activity area had been included in WCP-Water because of the great importance of the subject and the need to encourage national and international debate on the possible nature and magnitude of the ultimate impact on society of any change in climate. At the time of the Second Planning Meeting on WCP-Water (November 1982), it was hoped that the UNEP Scientific Advisory Committee for the WCIP would formulate a project or projects which might be included under this activity area. The Third Planning Meeting on WCP-Water (November 1985) expressed the same hope. The current meeting was informed of the present and future activities of UNEP in relation to climate and water, as reported under 3.20 to 3.24 above, and suggested that some of these might usefully be written up as WCP-Water projects so that they could better be taken into account in WCP-Water planning.

F. Influence of Water-Resource Projects on Climate

The meeting was informed of the results of the Unesco/UNEP Symposium on the Impact of Large Water Projects on the Environment held in Paris in 1986. It was noted that only a few papers of the Symposium were related to the influence of water-resource projects on climate. The meeting expressed the opinion that further national studies are desirable.

## 5. TERMINATION OF PROJECTS AND DEVELOPMENT OF NEW PROJECTS

5.1 There were no proposals for the formal termination of projects. Projects A.6 and B.2 were combined with Projects B.3 and B.1 respectively, not because the work on them had been completed, but because it was seen as preferable to include the more specific activities under general headings rather than as independent projects.

5.2 Similarly, a number of new developments noted by the meeting were incorporated as activities under existing headings rather than as new projects.

5.3 Three new projects were added to the programme, namely B.5, D.7 and D.8. As regards B.5, this had been under implementation within IHP-III for some years and it was felt appropriate to include it as part of WCP-Water. Projects D.7 and D.8 were presented as proposals by the representative of FAO and their inclusion was warmly welcomed by the meeting. These three projects are described in the standard format in Annex 4.

5.4 In order to avoid confusion, it was decided to retain the current numbering system for WCP-Water projects. The full list of projects presented at the beginning of Annex 4 includes references to Projects A.6 and B.3 with annotations explaining that they have been incorporated in others. It was agreed that the numbering system would be reviewed in due course, but not until after the Second World Climate Conference (June, 1990).

## 6. FUTURE DEVELOPMENTS AND MEDIUM TO LONG TERM PLANS

6.1 The meeting recognized that the implementation of each of the WCP-Water projects was dependent on the planning cycles, decisions and funding of the various national and international agencies concerned. The value of WCP-Water planning meetings was in reviewing all the projects on a common basis at one time, but the plans for each of them will change in accordance with the policy and decisions of the relevant governing bodies concerned.

6.2 As regards further planning of WCP-Water activities in general, the meeting emphasized that the subject of climate-water interactions extended well beyond the traditional scope of hydrology and that more work would need to be undertaken in future on the basis of collaboration with experts and institutions from other disciplines.

6.3 As regards WMO, Tenth Congress had approved a detailed programme for the period 1988-1991 and a more general long-term plan extending until 1997. The Eighth Session of the WMD Commission for Hydrology would meet in October/November 1988 and Eleventh WMO Congress would adopt a detailed programme for 1992-1995 when it meets in 1991.

6.4 A major planning exercise for all components of the World Climate Programme was expected to follow from the Second World Climate Conference (June 1990). The meeting expressed a strong wish that hydrologists be properly involved in the Propositions and conduct of the Conference. It was felt that the achievements within WCP-Water should be reported to the Conference, with reference being made to problems and solutions concerning the impact of climate change on the hydrological cycle and water resources management both on the global and project scales.

6.5 With respect to Unesco, the future activities will fall within IHP-IV (1990-1995) "Hydrology and Water Resources for Sustainable Development in a Changing Environment". The 24th General Conference of Unesco will determine the Medium Term Plan (1990-1995) for the Organization. The Plan for IHP-IV as an integral part of this medium term plan will be adopted at the same time. The Intergovernmental Council for the IHP at its ninth Session in early 1990 will determine the programme for IHP-IV including details of activities for the period 1990-1991.

6.6 In view of the above, the meeting recommended that the Fifth Planning Meeting in WCP-Water be held in second half of 1990, possibly in Nairobi.



7. CLOSURE

7.1 The meeting reviewed the draft of its report, made various amendments and adopted the final text.

7.2 The participants warmly thanked, Mr. Refsgaard for the very effective manner in which he had chaired the meeting. They also expressed their gratitude to the secretariat for its support through the presentation of documents and preparation of the report.

7.3 The meeting closed on Friday 16 September 1988.

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**FOURTH PLANNING MEETING  
ON WORLD CLIMATE PROGRAMME-WATER**

Paris, 12-16 September 1988

AGENDA

1. OPENING OF THE MEETING
2. REVIEW OF RECOMMENDATIONS AND DECISIONS OF GOVERNING AND ADVISORY BODIES
3. GENERAL REVIEW OF CURRENT AND PLANNED AGENCY ACTIVITIES
4. IMPLEMENTATION OF WCP-WATER PROJECTS UNDER THE SIX ACTIVITY AREAS:
  - A. Studies of hydrological data in the context of climate variability and change
  - B. Modelling of the hydrological cycle
  - C. Application of climate information in the planning, design and operation of water-resource systems
  - D. Studies of the influence of climate change and variation on water resources
  - E. Impact of climate on society through water resources
  - F. Influence of man's activities on climate
5. TERMINATION OF PROJECTS AND DEVELOPMENT OF NEW PROJECTS
6. FUTURE DEVELOPMENTS AND MEDIUM- TO LONG-TERM PLANS
7. CLOSURE

## CLIMATE-RELATED ACTIVITIES OF UNEP

## 1. Current activities

- (i) *Development of policies to respond to climate change*
- (ii) *Inter-related bioclimatic and land use changes (European Workshop)*
- (iii) *Policy oriented assessment of the impact of climate change*
- (iv) *Vulnerability of food systems to climate: an integrated approach to climate impact assessment*
- (v) *Greenhouse gases: GEMS environment library series*
- (vi) *Implications of future changes in sea level, and increased storm frequency resulting from greenhouse gas warming*
- (vii) *Socio-economic impacts and policy responses resulting from possible climate change: a regional study – Southeast Asia*
- (viii) *World Conference on the implications of a changing atmosphere for global security*
- (ix) *Climate systems monitoring*

## 2. Planned activities

- (i) *The human response to global change programme*
- (ii) *Socio-economic impacts and policy responses resulting from future climate change: Brazil*
- (iii) *Workshops on the implications of future climate change in Africa*
- (iv) *Socio-economic impacts and policy responses resulting from possible climate change: Southern Africa*
- (v) *Socio-economic impacts and policy responses resulting from greenhouse gas warming in India and Bangladesh*
- (vi) *The vulnerability of island states to possible climate change with special reference to sea level rise*
- (vii) *Socio-economic impacts in the Soviet Union resulting from possible climate change*
- (viii) *WCIP/WCRP workshop on the use of numerical methods in climate change with special reference to the outputs of various GCM's*

- (ix) *International coordinating body for the assessment of the role of CO<sub>2</sub>, and other greenhouse gases in climate variations and associated impacts*
- (x) *The Second World Climate Conference (UNEP/ICSU/WMO)*
- (xi) *Public information policy on climate change*
- (xii) *World glacier monitoring*
- (xiii) *Effects of climate change in the Mediterranean basin*
- (xiv) *Co-operative work between GEMS/PAC and FAO*
- (xv) *UNEP/ILCA project on drought- monitoring using remote sensing*
- (xvi) *Impact of sea level rise on society*

These projects are listed randomly and no attempt has been made to give priority to them. It is possible that a number of them can be undertaken simultaneously. Further no time scale is given for the accomplishment of the listed projects. Human and financial resources limitations could affect the extent and timing of implementation of the proposed programme.

WORLD CLIMATE PROGRAMME - WATER  
(WCP-WATER)

ACTIVITY AREAS  
AND  
PRIORITY PROJECTS

As proposed by the Fourth Planning Meeting on WCP-Water  
(Paris, 12-16 September 1988)



Summary Listing of Activity Areas and Priority Projects for WCP-Water  
as prepared by the Fourth Planning Meeting on WCP-Water  
(Paris, September 1988)

- A. STUDIES OF HYDROLOGICAL DATA IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE
  - A.1 Analyzing Historical Hydrological and Related Information
    - IAHS with co-operation of Unesco, WMO, ICSU, other interested international bodies and national institutions
  - A.2 Analysing Long Time Series of Hydrological Data and Indices with Respect to Climate Variability and Change
    - WMO in co-operation with Unesco, IAHS and interested national bodies
  - A.3 Distinguishing Between the Influence of Man's Activity and Climate Variability on the Hydrological Cycle
    - Unesco and interested Member States
  - A.4 Monitoring of Glacier Fluctuations
    - ICSI (IAHS) With the support of Unesco and UNEP
  - A.5 Collection of Global Runoff Data Sets
    - WMO in collaboration with Federal Institute of Hydrology, Federal Republic of Germany
  - (A.6 Transfer of Hydrology Information to Grid Point or Grid Area Values)
    - incorporated into Project B.3
  - A.7 Global Energy Balance Archive (GEBA)
    - Swiss Federal Institute of Technology (ETH) with other national institutions and the World Radiation Data Centre, Leningrad.

## B. MODELING OF HYDROLOGICAL CYCLE

### B.1 Coupling of Physically Based Climate and Hydrological Models

- WMO in co-operation with Unesco, IAHS and national institutions

### (B.2 Development and Application of Second Generation Grid Orientated Hydrological Modelling Techniques)

- incorporated into Project B.1

### B.3 Development of Grid-Related Estimates of Hydrological Variables

- WMO in collaboration with national institutions

### B.4 Hydrological aspects of HAPEX

- WMO and ICSU in co-operation with national institutions

### B.5 Use of Atmospheric Moisture Transport Information for Water Balance Computations

- Unesco in co-operation with WMO

## C. APPLICATION OF CLIMATE INFORMATION IN THE PLANNING, DESIGN AND OPERATION OF WATER-RESOURCE SYSTEMS

### C.1 Application of Climatological Data and Methods to Water-Resource Projects

- WMO

### C.2 Application of Climate Information for Water Projects in the Sahel

- WMO, with participation of countries of the Sahel and in collaboration with UNSO, CIEH, AGRHYMET Centre and with the financial support of UNDP and other donors.

### C.3 Application of Climate Information to Irrigation Water Supply Assessments in Africa Using a Digital Geographic Information System Data Base

- FAO in co-operation with interested member countries.

### C.4 Application of Conditional Climatological Information to Water Supply Forecasting in the U.S.A.

- US National Weather Service in co-operation with other national agencies

### C.5 Re-analysis of Hydrological Observations in Czechoslovakia'

- Czech Hydrometeorological Institute

### C.6 Teleconnexion of the El Niño Phenomenon with Extreme Hydrological Events in South America

- WNO through the RA III Working Group on Hydrology

D. STUDIES OF THE INFLUENCE OF CLIMATE CHANGE AND VARIATION ON WATER RESOURCES

D.1 Sensitivity of Water-Resource Systems to Climate Variability and Change

- National institutions and WMO with contributions from Unesco, IIASA and IAHS

D.2 Use of Climate Data for the Study, Planning and Management of Water Resources

- Unesco with cooperation of WMO, UNEP, IIASA, IAHS and UATI

D.3 Study of the Impact of Climate Variability and Change on the Occurrence of Droughts

- Unesco in co-operation with WMO and IAHS

D.4 Study of the Impact of Climate Variability and Change on the Occurrence of Floods in Urban Areas

- National institutions and Unesco in co-operation with WMO, IAHS and UATI

D.5 Testing the Transferability of Hydrological Simulation Models

- National institutions with international co-ordination by WMO

D.6 Impact of CO<sub>2</sub> Induced Climate Change on U.K. Water Resources

- Institute of Hydrology, U.K., in co-operation with other national and regional bodies

D.7 Assessment of Impact of Possible Climate Change and/or Sensibility of Irrigation Systems Including Storage of Irrigation Water in Reservoirs

- FAO in co-operation with FAO Member countries

D.8 Assessment of Climate Change Impact on Population Supporting Capacity of Land Based on AEZ (Agro-Ecological-Zones)

- FAO

E. IMPACT OF CLIMATE ON SOCIETY THROUGH WATER RESOURCES

- no projects proposed at this stage-

F. INFLUENCE OF MANIS ACTIVITIES ON CLIMATE

F.1 Influence on Water-Resource Projects on Climate

- Unesco and UNEP in co-operation with national organizations

## ACTIVITY AREA A

### STUDIES OF HYDROLOGICAL DATA IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE

An analysis of historical hydrological data and information and in particular of long hydrological time series is being undertaken in order to gain fuller knowledge of climate variability and a better understanding of the processes related to climate change, including the influence of man on climate.

Due to the close relationship between climate and hydrology, hydrological variables and water resources are very strongly influenced by variations in climate. In this respect, hydrological variables, such as surface runoff, can be considered as "climate variables" representing on a large scale in time and space the residual of precipitation and evaporation.

In addition, a continuing inventory of water resources, their supply, demands and their dynamics, is needed to provide hydrological data (precipitation, runoff, glacier fluctuations, etc.):

- (a) to climate modellers for the validation of predictions ;
- (b) to researchers studying climate change and variability ;
- (c) to hydrologic modellers for validation of their models and methods and for use in sensitivity studies; and
- (d) for the application to food, energy, economic and health problems.

In relation to (a) above, new methodologies should be developed to relate hydrological and physiographic data to grid points or areas so that they might be used in conjunction with atmospheric general circulation models (AGCMs).

## Project A.1 Analyzing Historical Hydrological and Related Information

### 1. Background

Historical hydrological and related information, concerning for example floods, low flow periods or river ice periods, is available in many countries in the form of direct information stored in archives or in the form of indirect information such as proxy-data (i.e. ice core data, dendrochronological data, sediment probes, historical records tied to climatological or hydrological parameters, etc.). This material has been used for specific studies but could be more broadly used for increasing our knowledge of variations in hydrological regimes during past centuries. Such information would be useful for analyzing climate variability and change.

Several organizations, including some working within the framework of the WCP, have undertaken research in these fields. However, there is a need for more co-ordination between the individual research studies.

Research groups need information on existing inventories of historical hydrological data sources including proxy-data. Therefore, it would be necessary to compile information on existing data. Furthermore, a unified methodology is needed in the form of guidance material so that results of individual research groups can be compared.

### 2. Output

- (a) Improvement of methodologies and as far as possible unification of them;
- (b) Support for the work of and provision of guidance and information to research groups;
- (c) Comparison of results using various approaches for specific climatological or hydrological variables and for specific periods;
- (d) Increasing knowledge of variations in hydrological regimes during past centuries.

### 3. Past Activities

A circular letter has been sent out by IAHS to collect information as a basis for a review of the availability of historical hydrological and related information in member countries.

### 4. Further Implementation

The next stage of the project will be:

- to compile inventories of sources of historical data and proxy-data including:

- (i) acquisition of hydrological information from historical records and field data;
- (ii) extraction and processing of hydrological information into quantitative form;
- (iii) calibration of the quantitative form in order to allow comparisons with current data or experience;
- (iv) drawing conclusions from calibrated series concerning variability of the hydrological regime.

- to develop guidance material on the analysis of historical hydrological and proxy-data;

Detailed steps are/will be:

- (a) IAHS rapporteur for compiling of inventories and studies of hydrological historical sources and field data;
- (b) IAHS rapporteur preparing guidance material on the analysis of hydrological Information from historical records and field data.
- (c) Round-table discussion at the Conference on Climate and Water in Helsinki (September 1989) on the topics listed under 4. above
- (d) co-ordination meeting between projects A.1, A.2, A.3 and A.4.

B. Organizations/bodies involved

IAHS responsible with co-operation from Unesco, WMD, ICSU and other interested international bodies and national institutions.

6. Tentative time schedule

Based on (a) to (d) of 4 above:

- (a) 1988-1991
- (b) 1988-1991
- (c) 1989
- (d) 1991

7. Comments

This project involves the co-operation of many scientists from very different fields of research. This project started in 1983 and became operational only after several years.

Liaison necessary with Projects A.2 and A.3.

Project A.2 Analyzing Long Time Series of Hydrological Data and Indices with Respect to Climate Variability and Change

1. Background

In many countries long hydrological time series are available from instrumental records (e.g. of precipitation, discharge, water levels of rivers, estuaries, lakes). From these hydrological variables and relevant meteorological variables (e.g. air temperature) sets of hydrological statistics (annual mean, monthly mean, minimum values, exceedence for different time periods based on daily values, etc.) and indices (drought-index, etc.) can be obtained. This material should be used for improving knowledge of climate-variability by being analyzed in that respect. In some countries relevant investigations are currently being undertaken.

Research groups need information on existing long time series. Therefore, it will be necessary to compile information on such time series and their availability. Furthermore, a unified methodology is needed in the form of guidance material so that the results of individual research groups can be compared.

Long hydrological time series are often influenced by man's activities. These effects have to be identified and eliminated in the time series so as to isolate the influence of climate variability and change. A methodology for eliminating these effects is being developed under Project A.3..

2. Output

Results of analysing such long time series may give more detailed information on the variability of climate in time and space. The results will contribute to a better understanding of the physical processes behind climate variability and drainage.

3. Past Activities

During the first phase of the project a method for analyzing long-time series including a relevant computer programme was developed /WMO, WCAP Report No.3 (WMO/TD No. 224), 1988/.

4. Further Implementation

The next stages of the project will be:

- to compile information on existing time series, especially series starting before 1900;

- to apply the developed methodology to long hydrological time series;
- to develop procedures for analysis of processed time series with reference to global and regional variability and change;
- to develop analogous methodologies for analyzing other hydrological variables such as indices of extremes.

Detailed steps will be:

- (a) Member countries are being asked to identify and to analyze their long time series on the basis of the guidance material provided or alternatively to send their data to WMO for analysis;
- (b) An expert or institution should be found to consider the procedure for compiling the results of station analyses;
- (c) WMO to organize the compilation of results according to the procedure in b);
- (d) Round-table discussions to review results of analyses and to formulate and propose further procedures for analysis of other hydrological variables;
- (e) Co-ordination meeting to consider liaison with projects A.1, A.3, and A.4.

5. Organizations/bodies involved

The project is being executed by WMO in co-operation with Unesco, IAHS and with the participation of those Members which have available long hydrological time series.

6. Tentative time schedule

Based on (a) to (e) under 4 above:

- (a) 1988-1989
- (b) 1989
- (c) 1989-1990
- (d) 1991
- (e) 1991

7. Comments

Liaison with Projects A.1, A.3, and A.4.



Project A.3 Distinguishing between the Influence of Man's Activity and Climate Variability on the Hydrological Cycle

1. Background

The assessment of the influence of man's management activities on the hydrological cycle is central to the problem of modern hydrology, especially considering the increasing scale of river runoff regulation, groundwater utilization and general changes in the environment. However, there are difficulties in differentiating between the influence of climate variations and man's actions, in particular as regards long series of streamflows. Therefore a methodology for use in differentiating between these two influences has to be identified using long time series of hydrological and climatic data, statistical methods, models and experimental data.

2. Output

A report describing a methodology for distinguishing between the effects of man's influence and climate variability on the different elements of the hydrological cycle.

3. Past activities

- (a) The IHP Intergovernmental Council in 1984 appointed four rapporteurs for the Unesco/IHP-III Project 6.3 "Establishment of a methodology for distinguishing between man's influence and climate variability on the hydrological cycle, in particular streamflow and groundwater".
- (b) The first draft of the report was prepared in 1986 and reported in a paper (A methodology for distinguishing between the effects of human influence and climate variability on the hydrologic cycle by J.C. Refsgaard) presented at the IAHS Symposium on Influence of Climate Changes and Climate Variability on the Hydrological Regime and Water Resources, Vancouver, August 1987.
- (c) Working Group meetings were held for the rapporteurs in Paris, 18-22 May 1987 and in connection with the Fourth Planning Meeting on WCP-Water, Paris, 12-16 September 1988. It is noted that the final methodology agreed upon differs significantly from the preliminary one presented at the Vancouver Symposium.

4. Further implementation

- (a) The report will be finalized editorially.
- (b) The final report will be presented at the Conference on Climate and Water, Helsinki, 1989.

5. Organizations/bodies involved

The project will be executed by Unesco With the participation of Member States.

6. Tentative time schedule

- (a) Final report ready end of 1986
- (b) Publication as a Technical Report by Unesco 1989
- (c) Report to the Conference in Helsinki 1989

7. Comments

Liaison with Projects A.1 and A.2.

## Project A.4 Monitoring of Glacier Fluctuations

### 1. Background

In some alpine countries glacier fluctuations have been observed for many decades. Since 1960 glacier observations have been standardized on an international level and published on a five-year basis by the Permanent Service on the Fluctuations of Glaciers (PSFG). Four volumes of "Fluctuations of Glaciers" have been published.

Since 1976, the Temporary Technical Secretariat (TTS) for World Glacier Inventory has assembled national or regional glacier inventories using a computerized data system. This project was mainly complete by mid-1985, by which time a joint programme had been developed. This new programme combines the TTS and the PSFG. Reference glaciers are being chosen on the basis of the World Glacier Inventory and national inventories. These glaciers will be monitored in detail (annual mass balance).

### 2. Output

- (a) Record of long time series of glacier variations;
- (b) Monitoring climate variations in all glaciated regions on the basis of mass-balance studies of reference glaciers.

### 3. Past Activities

The World Glacier inventory is largely complete. Volume IV of "Fluctuations of Glaciers" (1975-1980) was published in 1985.

### 4. Further implementation

National correspondents (institutions) were invited to participate and these contacts are already well established. A central secretariat at the ETH in Zurich, Switzerland, is responsible for collection, assembling and publication.

### 5. Organizations/bodies involved

- (a) ICSI of IAHS with the support of Unesco and UNEP;
- (b) The ETH in Zurich, Switzerland furnishes the infrastructure of the secretariat;
- (c) National institutions as correspondents.

### 6. Tentative time schedule

1985-1990	Completion and publication of the World Glacier Inventory
1988-1990	Publication of Volume V of "Fluctuations of Glaciers" (1980-1985)

### 7. Comments

Liaison with Project A.1.

## Project A.5 Collection of Global Runoff Data Sets

### 1. Background

An international data base of hydrological data is considered as necessary for estimating land surface related hydrological inputs/ outputs of atmospheric general circulation models (AGCMs), for testing grid orientated estimation techniques for such inputs/outputs, for validation of AGCMs and other purposes. AGCMs use large scale grids of 2 1/2' or more (250 km x 250 km and larger) which are too large to be represented by single hydrological time series. Therefore, it is necessary to select hydrological data sets such as runoff values of small river basins (100-5000 km<sup>2</sup>) each representative of a hydrologically homogeneous region within the grid meshes. These data sets, once assembled, will also be of great value for a number of purposes other than the study and development of AGCMs.

### 2. Output

- (a) Global data base for surface water runoff from about 1500 selected stations ; daily and/or monthly values
- (b) Support for the development of AGCMs;
- (c) Service to other activities requiring such data.

### 3. Past Activities

- (a) Collection of daily runoff data for years 1978-1982 and related catchment maps;
- (b) Setting up a permanent "Global Runoff Data Centre" (GRDC)
  - (i) 1983-1987 at the Institute for Bioclimatology and Applied Meteorology of the University of Munich, FRG;
  - (ii) Since 1987 at the Federal Institute of Hydrology in Koblenz, FRG;
- (c) Including the monthly data up to 1979 published by Unesco in the "Discharges of Selected Rivers of the World";
- (d) Cooperation of the GRDC with the recently established Global Precipitation Climatology Centre (GPCC) in Offenbach, FRG.

4. Further implementation

- (a) Collection of runoff data for years 1983-84;
- (b) Collection of runoff data for subsequent years;
- (c) Processing and storage of data in GRDC;
- (d) Digitizing of catchment boundaries;
- (e) Maintenance of data centre and up-dating of data set;
- (f) Work-shops in Koblenz;
- (g) Further cooperation with the GPCC and other relevant global data centres.

5. Organizations/bodies involved

Based on (a) to (g) of 4 above:

- (a) and (b): WMO Secretariat
- (c) to (g): Federal Institute of Hydrology, Koblenz, Federal Republic of Germany.

6. Tentative time schedule

Continuing activity. First workshop under 4(f) in November 1988.

7. Comments

Liaison necessary with Project B.3 with regard to the derivation of grid-based values.

## Project A.7 Global Energy Balance Archive (GEBA)

### 1. Background

The amount and quality of direct measurements of energy- balance components increased substantially during the period 1965-1988. In regions with insufficient ground observations, and especially for oceans, the satellite based observations of radiation, surface roughness length and wind offer a new possibility for energy balance evaluation. This method, however, needs ground based data of high quality for the algorithm calibration and for verification.

The previously ignored flux of latent heat of melt should be taken into account in global energy balance. This component plays an important role for regions covered by seasonal snow cover and glaciers, not only in the energy balance but in the hydrological cycle. The latent heat of melt is the major heat sink during the summer on sea ice in polar regions

Recently it has become known that the energy fluxes show secular variations similar to those of air and sea surface temperatures. This tendency has been found in global radiation and net radiation and is considered to be related to the hydrological balance. This means that the secular variations in the hydrological cycle should be considered together with variations in energy balance. There are new conditions and requirements for energy balance data. Therefore, the Department of Geography of the Swiss Federal Institute of Technology in Zurich has initiated the work of collecting directly measured energy balance fluxes and com,-4-14-ng them into a computerized archives

### 2. Output

- (a) Computerized global archive of monthly and annual values of global radiation, direct solar radiation, diffuse sky radiation, short-wave reflected radiation or albedo, long-wave incoming and outgoing radiation, long-wave net radiation, net radiation, sensible heat flux, latent heat flux, subsurface heat flux, latent heat of melt and ultraviolet radiation.
- (b) Time series of some of the above mentioned fluxes for selected stations.
- (c) Ground truth for satellite-based estimations of energy balance fluxes on the earth's surface.
- (d) A new global atlas of energy balance.

### 3. Past Activities

Energy flux data have been extracted from 1000 publications and summarized as monthly means of energy balance components at 800 locations. Among these there are 133 stations with more than one year period of measurement. The data base schema has been designed and a data entry application program, including the "physically possible" data quality control, has been released for routine data input.

4. Further implementation

- (a) Collection and summarizing of energy flux data as monthly means and entry of monthly means into the data base.
- (b) Development of software for further quality control, statistics, graphics, and mapping.
- (c) Up-dating of the archives
- (d) Study of data scarce regions, especially polar regions and oceans.
- (e) Completion of the new global atlas.

5. Organizations/bodies involved

Department of Geography, Swiss Federal Institute of Technology (ETH): Building and updating the archive from 1985 and continuing after 1990.

World Radiation Data Centre, Leningrad.

Institute of Meteorology, University of Cologne : Evaluation of radiative fluxes over oceans, 1987-1989.

Department of Geography and Department of Cartography, Swiss Federal institute of Technology (ETH) Cartographic representation of energy balance, 1989-1991.

6. Tentative time schedule

Based on (a) to (e) of 4 above

- (a) Initial collection - 1985 to end of 1989
- (b) 1988-1990
- (c) on continuous basis after 1989
- (d) 1989-1990
- (e) end 1991.

7. Comments

Closely related to Projects A.3 and A.4. Expected to contribute to Projects C.1, C.3 and D.2.

## ACTIVITY AREA B

### MODELLING OF THE HYDROLOGICAL CYCLE WITH SPECIAL REGARD TO PROVIDING INPUTS FOR CLIMATE MODELS

The quantitative coupling of climate, hydrologic and water-resource systems can best be achieved within the framework of mathematical models of the hydrological cycle. However, nearly all existing hydrological models are river basin oriented and so are their atmospheric inputs and outputs (precipitation and evapotranspiration). This is one reason for the recent difficulties in coupling hydrological models with atmospheric general circulation models (AGCMs), the latter being generally grid oriented with standard grid scales of 5 or 2.5 degrees. Even when the hydrologic and climate models are not directly coupled but run in parallel, enormous difficulties exist in providing the required input data from one model to the other. For the same reason, it is impossible to make direct use of observed river discharges for climate studies over an area.

The most practical way of overcoming this difficulty would appear to be by developing and applying a second generation of grid-orientated hydrological modelling techniques which can take account of all land surface related moisture and heat fluxes. Outputs of these models are related primarily to grid areas. However, if one wishes to use the outputs for flow components (overland flow, percolation, interflow, base flow, streamflow) in any river basin studies then these outputs must first be related to basin divides. For this reason they must be routed and superimposed. With special regard to the storage and delay processes within the different hydrological subsystems of the river basin. This should be taken into account when using discharge records for such studies and, in particular, for validating AGCMS.

Thus, intensified research activities are required in the field of hydrological modelling in the framework of the projects listed below. It is quite obvious that for these projects causal physically-based models are preferred. The explanatory power of causal models makes them especially attractive to WCP-Water because they have 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 influence on the natural processes involved.

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 and a re-examination of the traditional dividing lines.



## Project B.1 Coupling of Physically Based Climate and Hydrological Models

### 1. Background

It is considered that the further development and improvement of physically-based mathematical models of the atmosphere would gain greatly from a better understanding of the effect on climate of hydrological processes and an upgrading of the manner in which such processes are incorporated into atmospheric general circulation models (AGCMs). This would be aided by the coupling of climate and hydrological models.

### 2. Output

Presentation of practical ways for bringing together results of physical climate and hydrological modelling in order to accommodate the physically based relationships (feedbacks) which are mostly being neglected in the current practice of modelling;

Specifications of input data requirements to be considered by:

- climate modellers
- hydrologic and water-resource system modellers.

Improved methods (hydrological models) and computerized technologies for estimating water transfer at the land surface, in particular areal evapotranspiration, dependent upon climatic, physiographic and other characteristics (e.g. soil, land use, vegetation, geology).

### 3. Past Activities

Progress continues to be made in improving the incorporation of hydrological processes in AGCMS.

The Co-ordination Meeting for Implementation of WCP-Water Projects, held in Geneva in November 1986, discussed this subject and its report /WCP Report No. 129 (WMO/TD No.169)/ provides useful information.

Partly as an outcome of that meeting, Messrs. Becker and Nemeč have developed a proposal for hydrological models which might be used to link with climate models. This is described in "Macroscale hydrological models in support to climate research" by A. Becker and J. Nemeč, Proceedings of the International Symposium on the Influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources, Vancouver, August 1987, IAHS Publ. No. 168, 1987.

### 4. Further Implementation

- (a) 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 primary objective would be to propose specific research projects and approaches that seem promising for coupling physically based climate and hydrological models;

A second objective would be to agree on guidelines as to how appropriate scenarios of climate change and variation should be established which can then be taken as inputs into hydrological and water-resource system models for investigating the influence of climate change and variation on these systems and for sensitivity analyses;

- (b) Follow-up action on basis of workshop proposals.

5. Organizations/bodies involved

International organizations with WMO as lead agency in co-operation with Unesco, IAHS and national institutions.

6. Tentative time schedule

- Informal discussion mid-1989;
- Workshop 1991;
- Follow-up action, possibly in conjunction with Project B.3, after 1991

## Project B.3 Development of Grid-related Estimates of Hydrological Variables

### 1. Background

No widely accepted Methodology exists for transferring information from hydrological stations to grid points or areas. Such a methodology is required, however, for making use of information on observed streamflow in the development and use of atmospheric general circulation models (AGCMS) (see WCP-Water Project A.5) and for developing grid-based hydrological models (see WCP-Water Project B.1). The use and integration of remote sensing information also needs to be considered in this context.

### 2. Output

- (a) A methodology and generalized procedures for the transfer of hydrological information, as well as physiographic and other characteristics to grid point on grid area values.
- (b) One such methodology for use in treating the data held by the WY.0 Global Runoff Data Centre (GRDC).

### 3. Past activities

A state-of-the art report on grid-point and grid-area estimates has been prepared as a draft.

### 4. Further implementation

- (a) Review of the above draft report, at the Koblenz Workshop (see WCP Project A.5) and its finalization;
- (b) Preliminary selection of one or more methodologies to be used by the GRDC;
- (c) Development of proposals on the basis of discussions at the workshop;
- (d) Meeting of experts to elaborate the project proposal and plan co-ordination of national activities for the development, verification and application of existing procedures;
- (e) Case studies by national institutions;
- (f) Co-ordinated review of case study results and development of conclusions.

### 5. Organizations/bodies involved

WMO in collaboration with national institutions.

### 6. Tentative time schedule

1988-1992

### 7. Comments

Liaison with Projects B.1 and B.4.

## Project B.4 Hydrological Aspects of HAPEX

### 1. Background

There is ample evidence of the sensitivity of climate changes in heat and moisture fluxes at the land surface. The purpose of the WCRP project for Hydrological-Atmospheric Pilot Experiments (HAPEX) is to improve our understanding of the processes involved and to provide a basis for developing and testing improved parametric formulations of these processes for use in atmospheric circulation models. HAPEX field studies will collect comprehensive sets of hydrological, atmospheric and related data for a number of specific sites.

### 2. Output

Sets of original and processed data from HAPEX field studies stored at a central repository or repositories.

### 3. Past Activities

- (a) HAPEX-MOBILHY, S.W. France, 1985-86
- (b) First ISLSCP Field Experiment (FIFE), Kansas, USA, 1987
- (c) Land surface process experiment, Kursk, USSR, 1988

### 4. Further Implementation

- (a) Heihe River Basin Experiment, China, 1989;
- (b) ISLSCP Experiment in Niger, 1950;
- (c) Storm Central experiment, Central Great Plains, USA, 1990;
- (d) Longitudinal Trajectory Experiment, planned by Federal Republic of Germany;
- (e) Land surface processes/hydrology experiments;
- (f) Collation and storage of HAPEX data sets;
- (g) Distribution of the data sets.

### 4. Organizations/bodies involved

National institutions, individually or in multi-lateral co-operation. WMO/ICSU under WCRP at international level.

### 5. Tentative time schedule

Continuing, each experiment having its own time schedule.

### 6. Comments

Liaison with Projects B.1 and B.3.

## Project B.5 Use of Atmospheric Moisture Transport Information for Water Balance Computations

### 1. Background

The hydrological cycle is an essential part of the climate system and the atmospheric part of the hydrological cycle is an essential part of that cycle.

For the determination of water balances of large basins and areas knowledge of atmospheric moisture transport is indispensable. A better knowledge of atmospheric moisture content and transport in relation to surface hydrological processes will also facilitate making the necessary links between hydrological models and global circulation models in the framework of the studies of the impact of climate variability and change on water resources.

### 2. Output

- (a) Preparation of a technical report and case studies on the use of data on atmospheric moisture transport over continents and large river basins for the estimation of water balances and other purposes.
- (b) Increased knowledge about the possibilities of using aerological methods for linking surface hydrological and climatic knowledge in the framework of climate change studies.

### 3. Past Activities

The IHP Intergovernmental Council appointed a rapporteur in the framework of IHP-III Project 1.1 to prepare the report mentioned under 2 (a). A draft of the report was discussed at the Fourth Planning Meeting for WCP-Water.

### 4. Further implementation

The report on the use of data on atmospheric moisture transport over continents and large river basins for the estimation of water balances and other purposes will be published before the end of 1989 by Unesco.

### 5. Organizations/bodies involved

Unesco in co-operation with WMO.

### 6. Tentative time schedule

1989 Publication of report referred to under 2(a) above.

## ACTIVITY AREA C

### APPLICATION OF CLIMATE INFORMATION IN THE PLANNING, DESIGN AND OPERATION OF WATER-RESOURCE SYSTEMS

Water-resource projects can sometimes be planned, designed and operated purely on the basis of hydrological data. When such data are not sufficient, use must be made of other data, particularly climatological data. Even when a reasonable to good set of hydrological data is available, the use of climatological data can greatly improve the planning and design. In many cases the only local data are climatological and these must be used to derive estimates of hydrological and water-resource parameters for the localities concerned.

Long-range weather outlooks for periods of one to three months hold great potential for the improved management of water resources through their use in deriving predictions of future water supply and demand. The current uncertainty in these predictions means that a probabilistic approach needs to be taken.

There is a need for studies and guidance as to what climate information can be used and how in the planning, design and operation of water-resource systems. Future improvements in long-range climate predictions should be followed with a view to their being used to enhance water-resource management practice.

Project C.1 Application of Climatological Data and Methods to Water-Resource Projects

1. Background

The planning, design and operation of many water-resource projects is based in large part on the analysis of climatological data. Current practice already demonstrates the value of this approach and can provide the basis for the development of guidance on the subject.

2. Output

Guidance on the application of climatological data and methods to water-resource projects.

3. Past Activities

Literature searches and review.

4. Further implementation

Preparation of a technical report.

5. Organizations/bodies involved

WMO through CHy rapporteur and/or consultant.

6. Tentative time schedule

1988-1991	Continued accumulation of material
1991	Preparation of report, contingent on CHy discussion

7. Comments

Liaison with Project D.2.

## Project C.2 Application of Climate Information for Water Projects in the Sahel

### 1. Background

Nowhere has the impact of climate variability been more evident in recent years than in the Sahel. The central factor in all considerations of the droughts and desertification is the shortage and unreliability of water supplies. Of all regions, therefore, the Sahel is one where all available information should be used to ensure the best designed and most efficiently operated water projects. This includes the use of climate information in the planning, design and operation of such projects.

### 2. Output

- (a) Guidance on the use of climate information in conjunction with hydrological data for the design and operation of water projects, in particular where such information and data are scarce;
- (b) Contributions to studies of the impact on water systems of climate variability in the Sahel;
- (c) Assistance in the practical application of climate information for water projects in the Sahel.

### 3. Past Activities

- (a) Report on the derivation of design floods for small basins in the Sahel was prepared by WMO in 1984 with the support of UNSO;
- (b) A mission visited Niger in 1985 and prepared a report entitled "Application of Climate Information and Hydrological Forecasts for the Sahel";
- (c) A technical meeting on hydrological design criteria for use in the Sahel was held in Dakar in 1986 with the support of WMO, CIEH and UNSO.

### 4. Further implementation

The above outputs will be achieved through a series of activities undertaken as the opportunity arises and as funds permit, principally in collaboration with other international and regional bodies.

The AGRHYMET Programme (including the AGRHYMET Centre in Niamey) provides an infrastructure, including a data base and computer facilities, and pursues a programme of activities closely related to the subject of this project.

The United Nations Sahelian Office (UNSO) and the Comite Inter-africain d'Etudes Hydrauliques (CIEH) are both involved in related activities.



Certain activities of a technical assistance nature may be undertaken with the financial support of UNDP or WMO's Voluntary Cooperation Programme (VCP).

5. Organizations/bodies involved

WMO, with the participation of the countries of the Sahelian region and in collaboration with UNSO, CIEH and the AGRHYMET Centre and with the financial support of UNDP and other donors.

6. Tentative time schedule

Continuing activities similar to those recorded under 3. above, as and when the opportunity arises.

Project C.3     Application of Climate Information to Irrigation Water Supply Assessments in Africa using a Digital Geographic information System Data Base

1.     Background

A digital geographic information system (GIS) data base for Africa has been prepared by FAO with UNEP funding in connexion with a desertification study. Twenty-three maps have been digitized and processed at a scale of 1 to 5 million including political boundaries, soils (FAO soil map), geology (Unesco map), watersheds, annual rainfall, river systems and physiography. Because of FAO's emphasis on Africa and the need for consistent information on water and irrigation potential, the Africa GIS is being used as a basis for developing a methodology for water supply assessment on a regional and continent-wide basis.

2.     Output

Climate information (precipitation of different periods, temperature, evapotranspiration) combined with elementary water balance principles is used to develop an assessment of water supply for irrigation systems in Africa. More detailed assessment will be prepared for selected basins, first in the IGADD countries.

3.     Past Activities

The basic methodology was developed and water potential for irrigation in Africa, on a scale 1:5,000, was published in 1987. The publication is available on request.

4.     Further implementation

The study will now be made on a larger scale (1:1,000,000) for selected IGADD countries (Nile Basin). A more sophisticated water balance model will be used.

5.     Organizations/bodies involved

Water Service in the FAO Land and Water Division is performing the work with the cooperation of countries in the Nile Basin belonging to IGADD.

6.     Tentative time schedule

The project initiated in 1985, first phase terminated in 1987, second phase will last until 1991.

Project C.4     Application of Conditional Climatological Information to Water Supply Forecasting in the United States of America

1.     Background

Monthly weather outlooks are made by the US National Weather Service's Climate Analysis Centre. These can lead to a positional\* or conditional climatology appropriate to the present state of the climate System. This climatology, together with current and historical time series of hydrometeorological data, can then be used as input to hydrological models to produce an ensemble of possible future streamflow hydrographs which can then be analyzed in a statistical sense to Produce probabilistic Extended Streamflow Predictions (ESP's) for specified time periods in the future. The NWS's Office of Hydrology and related components will produce such forecasts for selected basins and these will be evaluated from the standpoint of their usefulness for water managers who must make decisions on possible operational alternatives for various water-resource systems.

2.     Output

- (a)     Prototype for the potential application of climate information in water-resource management;
- (b)     Evaluation of improved skill achieved in Extended Streamflow Predictions for monthly and seasonal time periods through the incorporation of positional climatological information;
- (c)     Formulation of objective procedures for incorporating positional climatological information into hydrologic forecasting methodology to produce probabilistic Extended Streamflow Predictions;
- (d)     Report describing results of project, including procedural recommendations and recommendations for future development and research.

3.     Past activities

- (a)     Many data have been collected for the Data Base of Positional Climatological Information;
- (b)     Alternative procedures for incorporating positional climatological information have been coded into the ESP program.

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\*     Positional climatology in this context is that climatological information and forecasts which allows one to position or weight historical time series Of hydrometeorological data in relation to current weather patterns so that they may be used in hydrologic simulations leading to probabilistic Extended Streamflow Predictions.

4. Further implementation

- (a) Further collection of data for the Data Base of Positional Climatological Information;
- (b) Development of an objective approach to using the procedure referred to under 3 (b) above;
- (c) Implementation of procedures for selected river basins in conjunction with the River Forecast Centers concerned;
- (d) Evaluation of improved skill achieved in probabilistic ESP with incorporation of positional climatological information;
- (e) Refinement and revision of techniques, and final testing;
- (f) Prepare final report.

5. Organizations/bodies involved

The principal organization involved in this project will be the US National Weather Service in cooperation with other water and climatological organizations in the USA.

6. Tentative time schedule

Ongoing with the aim of preparing a final report in 1990.

## Project C.5 Re-analysis of Hydrological Observations in Czechoslovakia

### 1. Background

Hydrological and related climatological data have been collected and stored in Czechoslovakia for many decades. They have been analyzed as a basis for evaluating the country's water resources and for other purposes. From time to time such evaluations are revised to take account of new data that have become available and/or amendments to national water policy. Recent developments in our understanding of climate, its variability and its impact on available water resources may lead to new approaches in the assessment --f water resources and call for a re-analysis of the existing hydrological records.

### 2. Output

- (a) Review of existing national methodologies for the analysis of hydrological data and the assessment of available water resources;
- (b) Review of international guidance in this field, in particular in association with Projects A.2 and D.1, and their pilot application in Czechoslovakia;
- (c) Re-analysis of certain hydrological and climatological observations in Czechoslovakia;
- (d) Proposals for further development and future application of Methodologies at national- and international levels.

### 3. Past Activities

During the last two years, following the conclusions of the Implementation Meeting held in September 1986, a pilot study covering a wide variety of sub-projects has been carried out. It deals with the selection of suitable methodologies, available data review, time schedule and organizational arrangements for each of the three parts of the project. The sub-projects are classified by their subjects into one of the following sections :

- (a) Analysis of long-time hydrometeorological series;
- (b) Re-analysis of hydrometeorological characteristics;
- (c) Changes in water balance.

The preparation of input data has also been partially completed.

4. Further implementation

The plan for the project in the future includes:

- (a) preparation of input data sets and the input information required;
- (b) development of computer programs;
- (c) data processing on a global scale;
- (d) analysis of results, recognized trends and supplementary processing;
- (e) draft of the report, tables, maps and graphs;
- (f) the final step is the publication of results.

5. Organizations/bodies involved

The Czech Hydrometeorological Institute, Prague.

6. Tentative time schedule

Based on (a) to (d) of 2 above

- (a) 1986-1989
- (b) 1989-1994
- (c) starting 1986
- (d) 1994.

7. Comments

This project will be closely coordinated with Projects A.2 and D.1.

Project C.6     Teleconnexion of the El Niño Phenomenon with Extreme Hydrological Events in South America

1.     Background

The meteorological anomalies, in particular those relating to precipitation, which are associated with the El Niño phenomenon affect the hydrological regime in those regions of South America situated on the western side of the continent.

It is also felt that these anomalies may be at the origin of droughts and floods affecting the eastern side at distances of 2000 kilometres and more.

A better understanding of the situation, besides being of considerable scientific value, would lead to the very practical application of improving hydrological predictions for the sub-regions concerned.

2.     Output

- (a) Preliminary selection of sub-regions (catchments) Which have apparently been affected by hydrological extreme phenomena (floods, droughts) in connexion with El Niño phenomenon;
- (b) Definition of the possibility of utilizing these catchments for developing studies aimed at determining a teleconnexion between the phenomena, including consideration of types of studies, data needs and availability and logistic support;
- (c) Final selection of catchments and methodologies to be applied and assembling of both meteorological (El Niño) and hydrological (catchment) data;
- (d) Analysis (modelling, correlations, etc.)
- (e) Reporting on the results of the study.

3.     Past Activities

The relevant information on the subject was being collected as a basis for the rapporteur's report. Arrangements were being made for the report to be completed in time for the session of the working group scheduled for 1989.

4.     Further implementation

The activities leading to the above outputs will be undertaken by national hydrological organizations with the co-ordination of the Working Group on Hydrology of WMO Regional Association III (South America).

5. Organizations/bodies involved

WMO through the RA III Working Group on Hydrology.

6. Tentative time schedule

Different outputs, as indicated in 2 above will be achieved as follows:

- (a) 1988
- (b) 1988-1989
- (c) 1989-1990
- (d) 1990-1991
- (e) 1991

7. Comments

Liaison with Project D.1.



## ACTIVITY AREA D

### STUDIES OF THE INFLUENCE OF CLIMATE CHANGE AND VARIATION OF WATER RESOURCES

The projects under this activity field are divided into 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 in climate inputs, whether actual, predicted or presented only as possible future scenarios. This activity therefore includes all sensitivity analyses, whether on hydrological variables or on water-resource decision variables (Project D.1).

The second class of projects is inspired by the recent altered perspective on climate, i.e. that it is in continual motion. 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 (e.g. aquifer level, runoff volume, flood frequency distribution), and water-resource decision variables (e.g. 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 directly and simply estimate the effect of an alteration in the governing hydrological variables on the derived water-resource variable.

The question of establishing appropriate scenarios for climate changes and variations to be expected within the planning period of important water-resource projects is covered under Activity Area B.

## Project D.1 Sensitivity of Water-Resource Systems to Climate Variability and Change

### 1. Background

Hydrologists, water-resource planners and managers are increasingly alerted to the differences in the properties of climate and hydrological quantities as measured over different time periods. This realization, and the need to take action, exist independently of whether the differences are the product of sampling variability or intrinsic non-stationarity due to climate change. The problem is especially acute in arid and semi-arid regions where variability, for example in annual runoff, is already high so that stable water-resource schemes to compensate for the uncertainly and shortages of supplies is most vital. This project addresses directly the responsibility passed by the Villach Conference in 1985 to the scientific community to reduce the uncertainty in forecasting the impact of greenhouse gas induced change and in framing policies to meet the impact.

### 2. Output

- (a) The enhancement of our understanding of the origin of interannual and seasonal variability and the persistence properties of salient hydrological variables;
- (b) An increase in our application of the performance of different hydrological modelling techniques in replicating the response to climate 4-nputs;
- (c) Estimates of the sensitivity of hydrological and water-resource qualitative and quantitative outputs due to possible changes in climate inputs-using scenarios within the limits of climatological studies.
- (d) Policy implications of climate change to water-resource management and planning.

### 3. Past Activities

- (a) International Symposium, on the Influence of Climate Changes and Climatic Variability on the Hydrologic Regime and Water-Resources, Vancouver, August 1987, organized by IAHS with sponsorship of WMO and Unesco. Proceedings: IAHS Publ. No. 168, 1987.
- (b) Norwich meeting which reviewed procedures for developing scenarios and made future research recommendations across a broad spectrum of interest including Project D.I. Water Resources and Climate Change: Sensitivity of Water-Resource Systems to Climate Change and Variability - Report of a workshop held in Norwich, UK (March 1987), WMO/WCAP Report No.4, 1968.

- (c) Material prepared by the CHy Rapporteur on WCP-Water:
  - (i) bibliographic review of published literature on scenario development for hydrological and water-resource sensitivity;
  - (ii) reports on policy advice on climatic change for water-resource managers and planners.

4. Further implementation

It is felt that the larger part of the effort should be devoted to the problem of change in hydrological output expressed as a function of a given change in climate input (mainly precipitation). Large basins which illustrate different rainfall and temperature regimes should be selected. All forms of modelling and approaches should be encouraged ranging from simple water and energy balance formulations to conceptual models. However, more emphasis should be given to those models which successfully passed the tests suggested under Project D.5.

Policy implications should first be agreed with the WMO Commission for Hydrology and Executive Council, then with relevant technical agencies and national members.

5. Organizations/bodies involved

Research at national level.

WMO at international level, with contributions from Unesco, IIASA and IAHS.

6. Tentative time schedule

1988-1996	National research and development
1989	Workshop at the WMO Conference on Climate and Water (Helsinki, September 1989)
1989-1991	Development of policy advice and passing advice through technical agencies and national membership
1992	Second 'Norwich' workshop

7. Comments

Closely linked with Project B.1 and the outcome of the workshop foreseen for that project and with Projects D.2 and D.5. Future contacts with ICOLD, ICID, IWRA, IWSA with respect to policy response.

## Project D.2 Use of Climate Data for the Study, Planning and Management of Water Resources

### 1. Background

The relationship between climate and the water-resource system on the earth is unique in the sense that parts of the hydrological cycle, namely precipitation and evapotranspiration, are also important characteristics of climate. The hydrological cycle is in turn the very basis of availability of water resources. It is possible to consider hydrological processes as a transfer function from the climate system to the water-resource system and vice versa, the function being under different circumstances part of both systems. With the increasing use of water-resources the vulnerability of society with regard to fluctuations in water supply due to climatic variability is likely to increase. It is, therefore, important to promote the understanding and better use of climate information by hydrologists in order to improve the design of water projects, the use of existing knowledge on climate variability and its impact on water availability and on water-resource systems and society in general.

### 2. Outputs

- (a) Promotion of national studies that involve climatologists, hydrologists, water-resource systems specialists and decision makers;
- (b) Compilation and review of existing information on the relative vulnerability of different water-resource systems to climate variability and change,, this review being primarily for the information of hydrologists, water-resource systems specialists and decision-makers ;
- (c) Promotion of the introduction of climatology in to curricula for the training of water-scientists through the preparation of a source book on climatology for hydrologists and water-resource engineers.

### 3. Past activities

The IAHS Symposium on the ' Influence of Climate Changes and Climatic Variability on the Hydrological Regime and Water Resources was held in Vancouver in 1987. The proceedings were published by IAHS.

### 4. Further implementation

The IHP Council appointed rapporteurs in the framework of IHP-III Project 3.1(b) to prepare a source book on climatology for hydrologists and water-resource engineers. A draft version of the source book was discussed at the Vancouver Symposium in 1987 and publication is planned for 1989.

### 5. Organizations/bodies involved

Unesco with co-operation of WMO, UNEP, IIASA, IAHS and UATI.

### 6. Tentative time schedule

Preparation and publication of source book.

### 7. Comments

Liaison with Projects C.1, D.1, D.3 and D.4.

Project D.3     Study of the Impact of Climatic Variability and Change in the Occurrence of Droughts

1.     Background

There is a need to provide hydrologists with advice on how to make better use of climatological information in order to enable them to better understand the occurrence of hydrological droughts, including associated climate events. The aim is to improve related risk assessment, planning and management for the prevention and mitigation of the consequences of the natural hazards concerned.

2.     Anticipated Output

- (a)    Promotion of national studies;
- (b)    Publication of a technical report.

3.     Past activities

First draft of the report was presented and discussed during the IAHS Symposium on the Influence of Climate changes and Climatic Variability on the Hydrological Regime and Water Resources, Vancouver August 1987.

4.     Further implementation

The technical report will be prepared by the rapporteur for the Unesco/IHP-III Project 3.4.

5.     Organizations/bodies involved

Unesco in co-operation of WMO and IAHS.

6.     Time schedule

Publication of the report by Unesco in 1989.

7.     Comments

Liaison with Projects D.2 and D.4.

Project D.4     Study of the Impact of Climate Variability and Change on the Occurrence of Floods in Urban Areas

1.     Background

Current design practice for urban drainage systems takes no account of possible climate change due to the effects on climate of the urban area. There is evidence of changes in rainfall rates and the incidence of heavy rainstorms which can cause more severe flood problems than hitherto.

2.     Output

Improved awareness amongst urban designers of possible greater vulnerability of current drainage systems to floods and the development of design modifications to overcome the hazard.

3.     Past Activities

None.

4.     Further implementation

It is foreseen that a related project will be established under IHP-IV (1990-1995).

5.     Organizations/bodies involved

National institutions and Unesco in co-operation with WMO, IAHS and UATI.

6.     Tentative time schedule

Not established.

7.     Comments

Liaison with Projects D.2, D.3 and with the WMO programme of activities in urban climatology.

## Project D.5 Testing the Transferability of Hydrological Simulation Models

### 1. Background

Remarkable progress has been achieved during the past period in the better understanding of problems related to the use of mathematical models of river basins for investigating changes in the hydrological regime due to climate variations (or changes) and/or other causes, such as land-use changes. Following this, consideration has turned to the usefulness, indeed the necessity, of testing more carefully the transferability of catchment models from gauged to ungauged basins or from given to changed conditions (climate or land-use changes, etc.), which is a prerequisite for the application of these models in studies of the effects of various changes in the physical conditions in a basin on its hydrological regime.

Moreover, it is felt that intensified activities in the development of hydrological models which meet the demands of physical soundness, geographic, climate and land-use transferability are most desirable and could contribute greatly to better solutions of the problems being considered within this activity area.

Long-term activities involving the testing of hydrological simulation models should continue. It is recognized that the testing of model transferability will require considerable research efforts and that, even if specific activities would be initiated immediately, it would take some time before results could be obtained which would contribute directly to the objectives of the WCP and the Operational Hydrology Programme of WMO. Because of this, the recommendation for the above project should not be construed as a recommendation to terminate studies of climate-impact assessment along the lines already pursued.

### 2. Output

Guidance and practical experience on the transferability of hydrological simulation models.

### 3. Past Activities

Publication by WMO in 1985 of WCP Report No. 98 - Sensitivity of Water Resource Systems to Climate Variability and the appearance of related papers in technical journals.

### 4. Further implementation

Further studies and testing of various hydrological models, including the national project being planned by the Danish Hydraulic Institute (DHI).

5. Organizations/bodies involved

National studies with international co-ordination by WMO.

6. Tentative time schedule

Continuous. DHI project planned for 1988-1990.

7. Comments

Liaison with Project D.1.



Project D.6 Impact of CO<sub>2</sub> induced Climate Change on UK Water Resources

1. Background

Britain as everywhere stands to be considerably affected by the global warming that is anticipated due to the increased concentration of CO<sub>2</sub> and other radiatively active gases in the atmosphere. The specific question has been asked - what is the possible effect on the country's water supply, particularly its surface water resources? The Institute of Hydrology (IH) has responded to this call and with the financial aid of several funding agencies has embarked on an appropriate programme of studies.

Specific objectives of the study will be:

- (a) the detection of existing climatic change as evidenced in the hydrological data of the UK;
- (b) investigation of scenarios for the impact of future change on extreme hydrological events;
- (c) effect of climate change on reliability of surface water and reservoir sources.

2. Output

- (a) Statistics of long-term runoff records including comparison of low flow and flood statistics by decade;
- (b) Evaluation of storage yield and other properties by climatic region in Western Europe;
- (c) Hydrograph comparison between global warm and cool periods;
- (d) Literature review of climate scenarios for CO<sub>2</sub> doubling in the European area for mean and variance of climate variables;
- (e) Estimate of low flow and reservoir reliability consequent on climate scenarios.

3. Past Activities

Progress has been made on the development of storage yield analysis programs and on scenario identification, including analogue regions. Flood and low flow series for North-West Europe have been studied for evidence of ongoing change on a continental scale.

4. Further implementation

A team will be assembled at IH to conduct the studies consisting of a hydrologist supervisor and a climatologist/statistician team leader with technical assistance from the existing Hydrological Extremes Section. Much of the data has already been collected under the auspices of earlier studies, e.g. FRENDO (Unesco IHP Project 6.1). Close liaison will be required with the Climate Research Unit of the University of East Anglia (Norwich, UK) for interpretation of climate model results and it is hoped that the Meteorological Office five and eleven level models can assist the study for special investigations. The creation of hydrologically homogeneous regions for low flows will be much assisted by the techniques and gridded geographic data base already available for Western Europe dating from the CEC European Flood Study.

It is also hoped to take advantage of parallel studies being undertaken in the UK concerned with impacts on land use and vegetation, and possibly also sea level rise. The analysis of long-term hydrological records will employ, among other techniques, the recommended procedures of Wk-,P-Water Project A.2. Particular attention will be given to tests based upon composite records and to derive quantities that relate to user needs.

5. Organizations/bodies involved

Primary responsibility lies with the Institute of Hydrology under contract to the Department of the Environment, overseas Development Agency, Water Authorities Association, D of E (Northern Ireland), Water Research Centre and possibly also the Commission for European Communities. Closely allied work is undertaken at the Institute of Terrestrial Ecology for biomass, and in European partners under CEC Climate Programme activities.

6. Tentative time schedule

The study will last three years from April 1987 although some preliminary work has begun, in particular literature searches.

7. Comments

Liaison with Projects A.1, A.2, A.3, A.4 and C.1.

Project D.7 Assessment of Impact of Possible Climate Change and/or Sensibility of Irrigation Systems including Storage of Irrigation Water in Reservoirs

1. Background

Several continents, Asia in particular, depend on irrigated agricultural production for feeding their population. Several preliminary studies were made by individual researchers and FAO on the possible impact of climate change on the availability of water for irrigated food production.

2. Output

An estimation of the degree of decrease of availability of water for irrigation, including the impact on storage reservoirs. Advice to be given to FAO member countries.

3. Past Activities

Methodological studies have been undertaken as described under 1. above.

4. Further implementation

Development of a generalized methodology to be recommended for detailed studies by individual countries.

5. Organizations/bodies involved

Water Service in the FAO Land and Water Division, subcontractors, FAO Member countries, authorities involved in irrigation.

6. Tentative time schedule

1989 Preliminary methodology  
1990 Final methodology  
1991 Publication.

7. Comments

This project is to be implemented in conjunction with Project D.B.

Project D.8 Assessment of Climate Change Impact on Population Supporting Capacity of Land Based on AEZ (Agro-Ecological Zones)

1. Background

FAO has developed a methodology to ascertain the population supporting capacity of land, using as input climatic, soil and crop production characteristics, spatially grouped by AEZ. This methodology was used with data available in the FAO Geographic Information System (including the FAO-Unesco soil map) and projections of the food production in the developing countries of the world were published. Climate change would no doubt alter these projections considerably.

2. Output

Projections of the population supporting capacity of land in different scenarios of a climate changed by the greenhouse effect.

3. Past Activities

These are as noted under 1. above.

4. Further implementation

The project is to proceed in phases. The first consists of the establishment of AEZs as the basis of various scenarios of climate change.

5. Organizations/bodies involved

FAO Land-and Water Division with subcontractors.

6. Tentative time schedule

The first phase is to take place in 1989-90, the second in 1991.

7. Comments

This project is to be undertaken in conjunction with Project D.7.

## ACTIVITY AREA E

### IMPACT OF CLIMATE ON SOCIETY THROUGH WATER RESOURCES

The impact of climate on society through water resources can be considered on several levels.

One is a simple statement of the type of impact that a climate change or variation has on the population of a given region either directly, 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 adaptative 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.

## AREA F

### INFLUENCE OF MAN'S ACTIVITIES ON CLIMATE

There is much interest in both scientific and more general circles as to whether man's activities are influencing or will influence the climate. It is proposed that such an influence might be exerted through changes in the hydrological regime. If such a proposition is to be seriously studied, there is need for an improvement of the representation of the climate forcing functions in the modelling of the hydrological cycle under man's intervention. Results of such studies would help to separate man-made changes in the hydrological cycle from natural variability and would also help to reconstruct non-influenced conditions.

Project F.1 Influence of Water-Resource Projects on Climate

1. Background

Water projects (e.g. reservoirs, diversions, irrigation and drainage works) may influence the micro-climate or possibly the meso-climate in their vicinity. In several countries an environmental impact assessment, including an assessment of climate change which may prove useful for the estimation of the effect of future water projects on climate.

2. Output

- (a) To detect the presence and scale of climate change resulting from existing projects under different climatic conditions;
- (b) To develop methods for the prediction of effects of water projects on climate, in particular for the purposes of environmental impact assessment;
- (c) To compile case studies on specific proposed water projects (e.g. reservoirs, diversions, irrigation and drainage works) on the climate;
- (d) Proceedings of International Symposium on the Impact of Large Water Projects on the Environment, Paris, October 1986.

3. Past Activities

The Symposium mentioned under 2 (d) took place-.The Proceedings will be published.

4. Further implementation

- (a) A survey by national organizations and/or consultants of available information on the influence of water projects of different types and sizes;
- (b) An analysis of such existing projects from the point of view of their impact on climate.

5. Organizations/bodies involved

Unesco, UNEP in co-operation with national organizations.

REPORTS PUBLISHED IN THE WORLD CLIMATE APPLICATIONS PROGRAMME SERIES

- WCAP - 1 CLIMATE AND HUMAN HEALTH. Proceedings of the Symposium in Leningrad, 22-26 September 1986, Volume I
- WCAP - 2 CLIMATE AND HUMAN HEALTH. Proceedings of the Symposium in Leningrad, 22-26 September 1986, Volume II
- WCAP - 3 ANALYZING LONG TIME SERIES OF HYDROLOGICAL DATA WITH RESPECT TO CLIMATE VARIABILITY - Project Description
- WCAP - 4 WATER RESOURCES AND CLIMATIC CHANGE: SENSITIVITY OF WATER-RESOURCE SYSTEMS TO CLIMATE CHANGE AND VARIABILITY. Norwich, U.K., November 1987
- WCAP - 5 FOURTH PLANNING MEETING ON WORLD CLIMATE PROGRAMME-WATER. Paris, 12-16 September 1988