WORLD CLIMATE PROGRAMME

APPLICATIONS

FIFTH PLANNING MEETING

ON

WORLD CLIMATE PROGRAMME-WATER

LAXENBURG, 30 APRIL-4 MAY 1990

WCAP – 11

WMO/TD-No. 374

UNITED NATIONS EDUCATIONAL
SCIENTIFIC AND CULTURAL
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 Fifth Planning Meeting on the World Climate Programme-Water was held at the International Institute for Applied Systems Analysis in Laxenburg, Austria, from 30 April to 4 May 1990. It was organized jointly by Unesco and WMO with the support of IIASA 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 At the opening Mr. B.R. Döös, Leader of the IIASA Environment Programme welcomed the participants to Laxenburg and Mr. A. Szöllösi-Nagy and Mr. A.J. Askew, speaking on behalf of the Director-General of Unesco and the Secretary-General of WMO respectively, 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, IIASA and IAHS.

1.3 Mr. Döös brought to the meeting the greetings of Mr. Z. Kaczmarek, Leader of the IIASA Water Resources Project, who was in hospital and therefore unable to attend and play an active role in the work of the group as he had intended. For his own part, Mr. Döös expressed his pleasure at being present at the fifth WCP-Water planning meting, as he himself had chaired the first meeting and had been gratified to note the considerable progress that had been achieved in the intervening nine years.

1.4 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, and the Second and Fourth Planning Meetings had been hosted by Unesco in Paris in 1982 and 1988 respectively. It was therefore seen as very fitting that the fifth meeting was now hosted by IIASA in Laxenburg.

1.5 Mr. M. Beran accepted the invitation to act as chairman of the meeting. He stated that it offered an excellent opportunity not only to review progress with all projects, but to recommend the finalisation of some and the consolidation of others. The timing of the meeting was particularly opportune as it allowed an input to the Second World Climate Conference, possibly the most important climate-related meeting so far.

1.6 The agenda of the meeting is given in Annex 2 to this report.

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.

Objectives of the World Climate Programme

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.

2.3 The WCP consists of the following four components:
World Climate Data Programme (WCDP);
World Climate Applications 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.

2.4 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.

2.5 While recognizing the historical and administrative reasons behind this sub-division into four components, the planning meeting felt that it 'could be somewhat confusing. It therefore expressed its preference for coordinating water-related activities with WCP without further reference to the sub-division.

World Climate Data Programme

2.6 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).

2.7 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 World Weather Watch 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

2.8 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.

2.9 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

2.10 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.

2.11 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

2.12 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.

2.13 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_2 and other radiatively active species in the atmosphere.

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

2.14 This conference was held in Geneva in March 1987. The conference reviewed the results achieved within the framework of the International Hydrological Progranune (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.

2.15 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

2.16 In May 1987 Tenth WMO Congress (Cg-X), 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 and with the valuable co-operation of other international organizations. Congress agreed that WMO should continue to take the lead in the overall co-ordination of the World Climate Programme.

2.17 The impact of man's activities on the natural environment was 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.

2.18 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.

2.19 At its forty-first session in June 1989, the WMO Executive Council confirmed that WMO should see its responsibility as being to provide the authoritative scientific information and advice on the condition and behaviour of the global atmosphere and climate and the factors that affect them. It noted the interest of governments to enter into a framework convention on climate change, based on the work of the Intergovernmental Panel on Climate Change (IPCC). Amongst other comments, the Council also encouraged countries to undertake field studies of atmospheric transport processes and land-surface hydrology, in the context of an international effort to better understand regional water resources and the global water cycle. Particular mention was made of the Global Energy and Water Cycle Experiment (GEWEX) in this context.

Eighth Session of the WMO Commission for Hydrology

2.20 The WMO Commission for Hydrology (CHy) met for its eighth session in Geneva from 24 October to 4 November 1988. It noted the report of the Fourth Planning Meeting on WCP-Water and took action to ensure that CHy would continue to make a direct input to WCP-Water activities.

2.21 The Commission also made extensive proposals for the revision and up-dating of WMO's long-term plan in the field of hydrology and water resources. In particular the Commission put increased emphasis on problems relating to the physical environment and to climate change. These proposals will be considered by Eleventh WMO Congress in May/June 1991 and include the following suggestion for the overall goal of WMO's Hydrology and Water Resources Programme:

> "To ensure the assessment and forecasting of the quantity and quality of water resources, in order to meet the needs of all sectors of society, to enable mitigation of water-related hazards, and to maintain or enhance the condition of the global environment."

2.22 The Commission adopted a Statement on the Hydrological and Water-Resource Impacts of Global Climate Change which was subsequently endorsed by the WMO Executive Council at its forty-first session. This statement is reproduced in Annex 3 to this report.

Twenty-Fifth General Conference of Unesco

2.23 The twenty-fifth General Conference of Unesco was held in November 1989 in Paris. The General Conference noted the successful completion of the Third Phase of the International Hydrological Programme and also endorsed the Draft Plan for its Fourth Phase as an integral part of Unesco's Medium Term Plan for 1990-1995.

Ninth Session of the Intergovernmental Council of the International Hydrological Programme

2.24 The Ninth session of the Council took place in Paris from 19 to 24 March 1990.

2.25 The Council reviewed the activities, undertaken 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.

2.26 At this session the Council also accepted the detailed Plan for the Fourth Phase of the IHP (1990-1995). This phase of the IHP bears 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 predict the consequences of possible climate change on the hydrological cycle.

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.

It was noted that CLICOM was being used in certain instances to handle hydrological data and that there had been some success in interfacing CLICOM with hydrological data base systems, most notably with certain HOMS components (Workshop on a CLICOM-HOMS Interface, Reading, UK, March 1990).

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.

3.3 Mention was also made of plans to carry out a Tropical Urban Climate Experiment (TRUCE), under the auspices of the WMO Commission for Climatology, and to revitalize the Climate Applications Referral System (CARS).

World Climate Impact Studies Programme

3.4 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

3.5 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.

3.6 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.

3.7 The meeting expressed considerable interest in the plans for GEWEX, particularly in view of the prominence given to hydrology in its objectives. The meeting looked forward to the publication of the Scientific Plan for the Experiment so that it might be possible to see clearly the role that the hydrological community will be called upon to play in its implementation. It urged the continued and strengthened involvement of hydrologists in GEWEX activities.

3.8 One point of specific interest to the meeting was the inclusion of the cryosphere in the plans for GEWEX. The hope was expressed that cryosphere data and the modelling of the dynamics of the cryosphere would be given the attention that they deserve.

The Intergovernmental Panel on Climate Change (IPCC)

3.9 Following two or three decades of climate research which led to the predictions of historically large global warming resulting from observed increases in the infra-red absorbing gases in the atmosphere, and the subsequent rising public concern, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in November 1988. The Panel has divided its work into four parts, each entrusted to a group (see accompanying block diagram):

- Working Group I on assessing available scientific information on climate change;
- Working Group II on assessing the environmental and socioeconomic impacts of such change;
- Working Group III on formulating response strategies to address climate change;

- Special Committee on the Participation of Developing Countries to promote, as quickly as possible, effective participation by the developing countries in IPCC activities.

3.10 The four groups will be completing their reports and summaries for policy makers in late May/early June 1990. Based on these, the Panel will write a report of findings and recommendations at its fourth plenary scheduled to be held in Sundsvall, Sweden, from 27 to 30 August 1990. This entire effort will constitute the IPCC first assessment report which will form part of the official documentation for the 45th (1990) session of the UN General Assembly and will be presented and discussed at the Second World Climate Conference (Geneva, 29 October-7 November 1990).

3.11 Issues associated with hydrology and water resources are explicitly treated only in Working Group II (Impacts). A draft version of the chapter in the Working Group II report focusing on Hydrology and Water Resources was completed in mid-April 1990 and distributed to participating IPCC countries by the IPCC Secretariat for review. This report, along with an associated 'Policymakers' Summary', will be finalized at the Working Group II plenary session in Moscow on May 28-30, 1990.

3.12 The elements of a possible framework convention on climate or climate change have been compiled by IPCC (Working Group III) as part of its work. The element about which there is little disagreement is that on research, systematic observations and analyses, and information exchange.

3.13 Water, in general, is a topic intrinsic to many, if not most, aspects of the IPCC assessment activity: e.g. predictions of changes in precipitation (Working Group I), resulting changes in hydrological conditions and water resources (Working Group II), and adaptation strategies to a changing equilibrium (Working Group III). However, the significant uncertainties associated with projections of precipitation severely restrict both the quantity and quality of assessments of the impacts on hydrology and water resources and, as a result, have engendered few concrete options for response or adaptation strategies.

Operational Hydrology and WCP-Water

3.14 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, especially those concerned with climate change and its consequences.

3.15 In 1988, CHY-VIII appointed rapporteurs to undertake work on the following topics:
(a) use of climatological data and climate information in hydrology and in water-resource projects;
(b) hydrological modelling for climate studies;
(c) operational hydrology and climate change.

INTERGOVERMENTAL PANEL ON CLIMATE CHANGE (IPCC)

IPCC

CHAIR: SWEDEN, VICE CHAIR: SAUDI ARABIA
RAPPORTEUR: NIGERIA

IPCC BUREAU

(15 MEMBERS)
CO-ORDINATING BODY DURING IPCC INTERSESSIONALS

WORKING GROUP I
SCIENCE

CHAIR: UK
VICE-CHAIRS:
BRAZIL
SENEGAL

WORKING GROUP II
IMPACTS

CHAIR: USSR
VICE-CHAIRS:
AUSTRALIA
JAPAN

WORKING GROUP III
POLICY

CHAIR: USA
VICE-CHAIRS:
CANADA
CHINA
MALTA
NETHERLANDS
ZIMBABWE

SPEC. COMMITTEE
DEVELOPING Cs.

CHAIR: FRANCE
ALGERIA
BRAZIL
INDIA
INDONESIA
JAPAN
KENYA
NORWAY
USA
USSR

WMO/UNEP JOINT IPCC SECRETARIAT
(LOCATED AT WMO, GENEVA)

Reports on these and other climate-related subjects are due to be completed by the time of the ninth session of the Commission in 1992.

3.16 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)

3.17 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 work of CHy and with the overall global activities under WCP-Water. The RAVI Working Group on Hydrology had recently completed a report on "Studies and models for evaluating the impact of climate variability and change on water resources within Regional Association VI".

Unesco International Hydrological Programme and WCP-Water

3.18 The Executive Board of Unesco, at its 129th and 130th sessions in 1988, laid the groundwork for Unesco's Medium-Term Plan (1990-1995) which was adopted by the Twenty-Fifth General Conference in November 1989.

3.19 One of the major programme areas in the Medium-Term Plan is "Science for Progress and the Environment". Within this programme area a large place is 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 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."

3.20 In the 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."

3.21 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.

3.22 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.

Theme H-4: The role of snow and ice in the global water cycle
- Project H-4-1: The effect of large-scale snow and ice covers on global and regional precipitation systems
- Project H-4-2: Snow and ice hydrology in specific areas and regions with special attention to long-term variations in storage.

FAO

3.23 FAO has 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.

3.24 In addition to the FAO WCP-Water Project C.3 on the water potential for irrigation in Africa, two other FAO projects are 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 continued co-operation with WCP in general and WCP-Water in particular.

United Nations Environment Programme

3.25 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.

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

3.27 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 Environmentally 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.

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

International Geosphere-Blosphere Programme:
A Study of Global Change (IGBP)

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

3.30 The ICSU Executive Board set up **a** Special Committee for the IGBP (SC-IGBP). The first meeting on the SC-IGBP 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."

3.31 The central goal of IGBP is to identify, quantify and predict the global environmental changes resulting from anthropogenic activities. Four coordinating panels have been established to investigate key areas for research, and working groups were set up to assess currrent and anticipated research capabilities in a number of areas.

3.32 Coordinating panel (CP3): Biospheric Aspects of the Hydrological Cycle has been charged with developing the hydrological part of the IGBP research programme. The main objective of the Core Project is to quantify the role of vegetation in the hydrological cycle and to predict the changes that may occur in the hydrological cycle due to anthropogenic large-scale perturbations of the vegetation cover and associated feedback effects. The core project calls for the development of a hierarchy of physically-based hydrological models, including SVAT (soil-vegetation-atmosphere) models, areally-integrated SVAT models, mesoscale and continental- to global scale models.

3.33 The coordinating panel (CP3) has stressed the need for active cooperation with WCRP/GEWEX, WCP/Water, IAHS, IHP-IV, IIASA/WAT. A joint IGBP/WCRP Ad Hoc Coordinating Group for Land Surface Experiments has been set up in order to promote close interaction between IGBP-CP3 and WCRP/GEWEX.

3.34 In the long term, the hydrological part of the IGBP will serve three main purposes:
(a) the provision of ground truth to validate GCMs
(b) to provide a basis for prediction of potential changes in terrestrial hydrological phenomena, driven by GCM-derived climatic scenarios
(c) to identify hydrological and vegetation parameters that could be used to monitor global climate changes.

European Programme on Climate and Natural Hazards (EPOCH)

3.35 This is largely a climate change programme with smaller components concerned with current climate hazards, e.g. desertification, and other natural hazards, e.g. landslides. Funding is available to the value of 40m European Currency Units and the process of selecting projects is, at the time of writing, close to completion and work will shortly commence. Projects will cover areas such as land phase process parametrization, plant water use, water resources impact and paleo-environments. Technological advances, e.g. monitoring and weather radar, will also be funded.

NATO Special Programme on the Science of Global Climate Change

3.36 The general objectives of the Programme are to promote research dealing with potential global changes within the Earth's environment system, using the means available to the NATO Science Committee. Those are essentially related with the funding of advanced level scientific meetings of two different kinds: the “Advanced Research Workshops”, which are international meetings held for two to five days for 20 to 50 prominent scientists from NATO or other countries with the objective of assessing the state-of-the-art in a given scientific area and to formulate recommendations to future research; the “Advanced Study Institutes” which are two-week international schools at post-doctoral level gathering together typically 12 to 15 lecturers and 60 to 80 students, with the objectives of disseminating advanced knowledge not yet in university curricula and fostering scientific contacts between senior and young scientists.

3.37 The Special Programme on the Science of Global Climate Change was created in the beginning of 1990 and will extend its activity till the end of 1995. It will particularly aim at describing and understanding the interactive physical, chemical and biological processes that regulate the total Earth system. Its primary goal is to advance our capability to predict changes in the global environment, in particular those which are related to human impacts on climate. The increase in tropospheric concentrations of greenhouse gases with its future effects on climate and on stratospheric ozone and other global consequences of human activity, such as deforestation and land uses, could indeed carry the threat to change global living conditions.

3.38 The research effort dealing with the climate system over the last decades shows that the development of a capability of prediction requires cooperative efforts to build models incorporating the relevant global physical, biological, chemical and geological processes. Much discussion and organizational efforts are going on at international and national levels along this line. However, multidisciplinary research is not developing at the rate required by our needs to understand better the environmental system. Most of the time, the effort continues to be confined to specific disciplines.

Research at the frontier of the traditional fields has not yet been tackled by multidisciplinary groups nor does strong interdisciplinary collaboration yet exist to investigate in depth the interactions and feedbacks between the different components of this environmental system: atmosphere, hydrosphere, cryosphere, biosphere and lithosphere. The specific goal of the proposed NATO Special Programme will be to promote such a collaboration between geologists, climatologists, hydrologists, chemists, ecologists and biogeochemists to study interdisciplinary processes playing an important role in the environmental system.

3.39 It is clear that a central focus is the role of the biosphere, how it affects the chemistry and composition of the atmosphere and how, through biogeochemical and hydrological cycles, it interacts with physical processes to produce the climate system of the Earth. The new Programme will therefore bring together scientists from various disciplines to exchange information dealing with complex interactions between the geosphere and the biosphere.

3.40 The NATO Programme will deal with the study of the positive and negative feed-backs, particularly within the following subsystems of the Earth: middle atmosphere-lower atmosphere; marine, terrestrial biosphere--ocean chemistry--ocean circulation; terrestrial biosphere-global climate; earth surface processes-global climate. The role of the hydrological cycle within the global climate system will also be considered. NATO involvement in the study of Global Climate Change will not be a duplication of ongoing effort, because none of the existing international programmes is mainly oriented toward providing the same mechanisms and support for international, interdisciplinary communication on specific research topics.

International Institute for Applied Systems Analysis (HASA)

3.41 IIASA is a non-governmental research institute created by 16 member countries from the West and East. The research conducted at IIASA is organised in the framework of programs covering the following areas: Environment, Population, Technology, Economy and Society, and System and Decision Sciences. Within the Environment Program there are four research projects dealing with various aspects of the environment protection and impacts of climate change. One of these, the Water Resources Project, addresses the development and application of methods and procedures needed to identify policy strategies for water resources development, management and operation through the use and evaluation of system analysis methods.

3.42 The objectives of the Water Resources Project are:

(a) To improve knowledge of the water-resource processes under changing demographic, economic, climatic and environmental situations.

(b) To develop methods for relating global climate variability and change to regional water resources.

(c) To study the sensitivity of water systems of various sizes to climatic change, on the basis of selected case studies.

(d) To provide methodological assistance to governments, international agencies and river basin commissions engaged in the development and operation of shared water resources.

3.43 Research is concentrated in two areas:

- Water Resources in a Changing Environment, dealing with the effects of climate on regional scale; specifically:
    - Development of methodologies for relating global climatic variability and change to regional water resources.
    - Development of impact assessment methods for water systems of various sizes - from a single reservoir to large international river basins.
    - Sensitivity analysis based on selected case studies under different climatic and hydrologic conditions.
- Management of River Basins, focused on methodological and practical aspects associated with decision making processes of water management in river basins, including:
    - To develop scientifically-based methods and tools to assist decision makers in solving problems of water management in river basins.
    - To distribute these tools to potential users and encourage their implementation.
    - To prepare educational programmes for introducing new methods and tools to professional water managers.

3.44 The results of the Water Resources Project activities are presented in reports and scientific papers. Certain of them also result in software (accompanied by appropriate documentation).

Development of WCP-Water projects

3.45 The meeting recalled that the World Climate Programme was both interdisciplinary 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.

3.46 The plans of UNEP and those of IGBP referred to under 3.25 to 3.34 above were seen as being very relevant to WCP-Water. The meeting therefore expressed the hope that relevant projects would soon be identified by UNEP and by ICSU for inclusion in the overall plan for WCP-Water.

Helsinki Conference

3.47 A Conference on Climate and Water had been convened by WMO and hosted by Finland in Helsinki from 11 to 15 September 1989 with the co-sponsorship of Unesco, UNEP, IAHS and IIASA. The aim of the conference had been to bring together experts involved in projects concerned with climatic variability and change and the impact on hydrology and water resources. It had provided an excellent forum for the discussion of the potential impact of climate change on water resources and was expected to make a direct contribution to the Second World Climate Conference. Its proceedings had been pre-published by the Academy of Finland.

3.48 A concise report of the Conference had been compiled by Mr. Beran from the summaries of proceedings prepared by topic rapporteurs. This report had been published with the support of the Academy of Finland and widely disseminated. The meeting was pleased to note that it was planned to provide copies of this report to participants at the Second World Climate Conference.

3.49 While the conference had been regional in character, having been based on Europe, its discussions had not been so limited and its report was seen as being of global relevance and widespread value.

The Second World Climate Conference

3.50 The Second World Climate Conference was scheduled to be held in Geneva from 29 October to 7 November 1990. The plans for the conference were discussed, the outcome being reported under section 6 below.

Comments of the Planning Meeting

3.51 The meeting was pleased to learn of the ever increasing level of activity on water-related climate topics. It saw this as being very welcome and appropriate in view of the importance of water in climate processes and of water resources in any studies of the impact of climate change.

3.52 It was recognized that it was not the role of WCP-Water planning meetings to control or manage activities. Their purpose was to review progress, comment, recommend and encourage activities as they saw fit. With this in mind, participants expressed some concern on two counts.

3.53 Firstly, it was noted that national water authorities which have for long been asked to cooperate in the regular programmes of the major bodies, such as the OHP of WMO and the IHP of Unesco, were now being called upon to help establish national committees for a range of new international initiatives, most notably the IGBP, GEWEX and the IDNDR. The latter, the International Decade for Natural Disaster Reduction, had been launched on 1 January 1990. It was not generally seen as being very closely linked to climate change issues and yet any such change could have a major impact on the magnitude and frequency of disasters of meteorological and hydrological origin. This served to illustrate why questions were being asked at national level as to the exact nature of and relationship between the various new and long-standing international water-related programmes. Stress was put on the need for the international organizations concerned to clarify this matter in their contacts at national level.

3.54 The second concern was more specific. It was felt that those who oversee the development of major new interdisciplinary programmes should stay in close touch with current activities under the parent disciplines. For example, IGBP and GEWEX should spawn many new studies and projects in hydrology and should invite feed-back from the expert hydrologists concerned over extended periods. The planning meeting welcomed the recognition by IGBR CP3 of the need for active cooperation with WCP-Water and expressed the hope that this would provide one route for hydrologists to participate in IGBP activities.

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 was pleased to learn that Mr. Pfister of Bern had agreed to write up the methodology and that IAHS planned to publish the text as a monograph in 1991.

A.1.2 It was noted that the response to the questionnaire on availability of historical information had been somewhat disappointing, although some good support has been obtained from the Working Group for Hydrology of WMO Regional Association VI (Europe). It was recommended that personal contacts be used to seek further information, the forthcoming XXth General Assembly of IUGG (Vienna, August 1991) offering an excellent opportunity in this regard.

A.1.3 One problem to be faced was that much of the relevant material was available only in the language of its compiler and this was often not English. However, it was noted that the intention was primarily to identify sources and that only summaries or abstracts are necessary for this purpose.

A.1.4 The meeting was also informed of plans for the International Council on Archives to undertake work in this general area in association with Unesco and WMO. It was recommended that when these plans were more fully developed, contact be established with Project A.l.

A.2 Analyzing long time series of hydrological data and indices with respect to climate variability and change

A.2.1 The meeting was informed of progress with the project as recorded in Annex 4. The WMO Secretariat was encouraged to follow-up on the offers of data which had not been received.

A.2.2 It was felt that the current computer programme might be amended, without too much effort, to include the analysis of annual time series developed for the exceedance of thresholds or falling below thresholds based on daily values. It was recommended that a small workshop be organized on this subject.

A.2.3 Now that Phases A and B of the project were underway, it was time to consider Phase C. A workshop would need to be held to develop plans for the interpretation of the analytical results. It was proposed that this might be held together with that referred to under A.2.2 above and involve a small number of experts not currently involved in the it project but who have experience in the analysis of climatological or hydrological time series. The IUGG Assembly in 1991 might provide a good opportunity.

A.2.4 A cautious note was raised as regards regional studies. Regional zonality can change significantly over time and using predetermined regions might exclude the possibility of mapping such zones.

A.3 Distinguishing between the influence of man's activity and climate variability on the hydrological cycle

The Working Group noted with satisfaction that the report by Messrs. J.C. Refsgaard, W.M. Alley and V.S. Vuglinsky on "Methodology for distinguishing between man's influence and climatic effects on the hydrological cycle" had been completed and published by Unesco in 1989 within the IHP Technical Documents in Hydrology (IHP-111 Project 6.3). The methodology is based on the joint application of statistical trend testing methods and hydrological (or statistical regression) models of streamflow or groundwater and is illustrated by case studies.

A.4 Monitoring of glacier fluctuations

A.4.1 This project is made up of two components: one concerning the World Glacier Inventory, and the second the study of the fluctuation of glaciers. Both are scientifically supervised by ICSI of IAHS. The World Glacier Inventory is an effort to make a snapshot image of the global glacierization for the time period of ca. 30 years from 1950s-1980s. In the inventory, main geometrical features of glaciers outside Greenland and Antarctica are considered.

A.4.2 The inventory of fluctuations of glaciers includes the records of changes in surface area, front position and mass balance of selected glaciers. The compiled results are currently published every five years. The sixth volume will be published for the five years data 1986-1990 within 1991. This series are accompanied with high quality glacier maps, for selected glaciers.

A.4.3 These activities are foreseen under two IHP projects (H-4-1 and H-4-2). These projects aim to study the relationship between snow, ice cover and ice sheet dynamics and global and regional precipitation patterns using global and mesoscale circulation models. The World Atlas of Snow and Ice Resources will also be completed and published within the framework of these projects.

A.4.4 The meeting recognized the importance and relevance of the current activities of glaciologists and urged that as much data on glaciers as possible are made available in computer compatible form for purposes of monitoring glacier changes and also for the modelling of land phase processes at the global scale.

A.5 Collection of global runoff data sets

A.5.1 The participants were pleased to note that within a few weeks of their last meeting, the Global Runoff Data Centre (GRDC) had been formally inaugurated by the Federal Republic of Germany under the auspices of WMO. It noted the report on its activities presented by Mr. H.J. Liebscher, the Centre's Director.

A.5.2 It was recognized that GRDC was now playing a major role in the international exchange of hydrological data. The Centre was encouraged to strengthen its work in this regard and the meeting fully endorsed the links it had established with UNEP's GEMS/WATER and GRID activities and the Global Precipitation Climatology Centre (GPCC) in Offenbach.

A.5.3 The WMO Secretariat was encouraged to continue its efforts to obtain additional data for inclusion in the basic data set, for both the extension of series already obtained and for achieving a more comprehensive coverage of the land surface of the world.

A.5.4 The meeting was informed of plans to establish a Steering Committee for GRDC, similar to that for GPCC, and saw this as a very appropriate mechanism for reviewing the Centre's past activities and advising it on its future plans. The establishment and operation of the GRDC as seen as one of the most valuable achievements of WCP-Water and the support of the Federal Republic of Germany, which was vital for this success, was gratefully acknowledged.

A.5.5 A proposal was accepted for a new project which would build on the work of the GRDC with the aim of detecting trends in runoff by monitoring the discharges of selected rivers. This is introduced as Project A.8 under 5 below.

A.7 Global Energy Balance Archive (GEBA)

A.7.1 Mr. A. Ohmura reported on developments in this project since the last planning meeting. He noted that progress had been a little slower than originally planned and that the current project was now expected to be completed in 1992 rather than 1991.

A.7.2 Discussions at the Fourth Planning Meeting on WCP-Water had identified new sources of data. The project had been extended to include additional energy balance components, such as sunshine duration, giving a total of 14 components in all.

A.7.3 All data were publicly available and were already being provided on request to GCM modellers and others and there was considerable confidence that the new global atlas of energy balance would be completed by 1992.

A.7.4 The meeting congratulated Mr. Ohmura and his colleagues on their excellent work and wished them every success with the final stages of their task.

B. Modelling of the hydrological cycle

B.1 Coupling of physically based climate and hydrological models

B.1.1 At the time of the last meeting, no major activities were planned for the project in 1989 and 1990. However, major developments, in particular in the planning of GEWEX, had given rise to a series of activities of considerable importance.

B.1.2 The international hydrological community, both through the IAHS/WMO Working Group on GEWEX and the eighth session of CHy, had taken initiatives and the meeting welcomed the active role now being played by hydrologists in developing improvements in the land-phase of GCM9.

B.1.3 While encouraging their colleagues to continue this direct collaboration with GCM modellers, the meeting also emphasized the importance of pursuing the development of macro-scale hydrological models such as that proposed by Becker and Nemec in 1987.

B.1.4 The meeting suggested that thought be given to bringing together those who are involved in macro-scale hydrological modelling under WCP-Water, GEWEX, IGBP and other international programmes so as to exchange experience and encourage collaboration between the individual experts and between the programmes themselves.

B.3 Development of grid-related estimates of hydrological variables

B.3.1 This project was seen as being very closely linked with Projects A.5 and B.1 and the meeting was pleased to note their parallel development.

B.3.2 The initiative taken by the IAHS/WMO Working Group for GEWEX had encouraged the development of plans for the Project for Gridded Estimates of Runoff over Central Europe. IIASA was thanked for hosting the planning meeting for this project in March 1990. Progress now depended on the national institutions concerned testing the various methodologies and making available their data.

B.3.3 The GEWEX Continental Scale Study would clearly need to make use of methods of gridding hydrological variables and it was therefore proposed that a direct but flexible link be established between it and the Central European Project so as to ensure a free exchange of ideas and experience.

B.3.4 The meeting welcomed the news that the newly-established FRIEND project would also be looking into this problem and that existing FREND data had already been analysed on such a basis in the UK.

B.3.5 It was recommended that the link referred to under B.3.4 be extended to cover all three projects and that thought be given to holding a workshop in 1991 or 1992 to which experts representing the three groups be invited.

B.4 Hydrological aspects of HAPEX

B.4.1 General information was provided on the latest developments as regards HAPEX. It was recognized that this comprised a loosely-knit series of national and regional projects each with similar but not identical aims and each requiring considerable resources.

B.4.2 Reference was made to the strong link between HAPEX and GEWEX and to the fact that, while HAPEX-type experiments were currently being implemented and would continue until the mid-1990s, GEWEX would only enter its practical phase in 1995.

B.4.3 It was seen as being important to keep Project B.4 in WCP-Water so as to monitor developments and to encourage the participation of, hydrologists and hydrological institutions in the planning and execution of the various experiments.

B.5 Use of atmospheric moisture transport information for water balance computations

B.5.1 A knowledge of atmospheric moisture content is indispensable for the determination of water balances of large basins and areas. The meeting noted that within Project B.5 a 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" had been prepared by L.P. Kuznetsova and was being published by Unesco as an IHP Technical Document in Hydrology.

B.5.2 This report deals with the analysis and generalization of the national research programme results of the last decade particularly with respect to reviewing new information on atmospheric water content and transport in connection with water balance computations. The report reviews water balances over the USSR, China, the Indian subcontinent and the Amazon basin. Case studies for water balance computations for the Parana, Volga, Ob and Irtys basins are also presented.

B.5.3 This completes Project B.5 for the present.

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 projects

C.1.1 As anticipated, the WMO Commission for Hydrology had assigned responsibility for the preparation of a report on this subject to a rapporteur. The expert concerned had prepared an outline of the document in October 1989. The final text should be completed by mid-1992.

C.1.2 The meeting recommended that the rapporteur take account of the methods used by FAO in their work on remote sensing.

C.2 Application of climate information for water projects in the Sahel

C.2.1 No specific activities could be reported under this project since the last meeting. The current difficult situation in the Sahelian countries made it unlikely that any activities could be conducted at national level in the foreseeable future unless major external funding was available.

C.2.2 Despite this, it was felt to be important to maintain the project as an indication of the importance that WCP-Water put on the use of climate information in sensitive regions and as a basis for encouraging those with the resources to assist in such work in the region.

C.3 Application of climate information to irrigation water supply assessments in Africa using a digital geographic information system data base

C.3.1 The meeting noted the progress being made in this project. It was seen as a pragmatic approach to a difficult problem.

C.3.2 It was suggested that more details might be provided as regards the current and potential use of remote sensing information in the project.

C.4 Application of conditional climatological information to water supply forecasting in the USA

C.4.1 The meeting was informed of developments in this project as reported by the US National Weather Service. It was pleased to learn that a report on the work would be completed within the very near future.

C.4.2 The National Weather Service also provided information on the work it planned to undertake on the verification of probabilistic streamflow forecasts. This was seen as so closely related to the general topic of Project C.4 as to be a part of it and the description of the project in Annex 4 to this report was therefore revised to incorporate this new activity.

C.4.3 CHY-VIII had requested its Rapporteur on Hydrological Modelling for Climate Studies to prepare a report on the topic covered by this project. This fact is also recorded in Annex 4.

C.5 Re-analysis of hydrological observations in Czechoslovakia

C.5.1 The status of this project was up-dated as indicated in Annex 4 on the basis of information received from the Czech Hydrometeorological Institute in Prague.

C.5.2 The meeting was interested to learn of the progress made.

C.6 Teleconnexion of the El Niño phenomenon with extreme hydrological events in South America

C.6.1 This project continues to be implemented under the auspices of WMO Regional Association III (South America). Its importance was evident at the time of the meeting because of the ENSO event that was gaining strength in the Pacific region at the time.

C.6.2 Those responsible for implementing the project were encourage to seek for and make use of information from outside RA III.

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

D.1.1 This was seen as an umbrella project which provided a means of recording and following-up on any of a wide range of activities concerned with this very important topic. Specific tasks undertaken by clearly identifiable groups were presented as separate projects under Activity Area D.

D.1.2 Particular note was taken of the WMO Statement on the Hydrological and Water Resource Impacts of Global Climate Change. The chairman of the meeting was congratulated on his role in its preparation.

D.1.3 The WMO Conference on Climate and Water (Helsinki, September 1989) was also seen as being a valuable contribution under this project.

D.1.4 The meeting proposed that copies of the report of the Helsinki Conference be sent to ICOLD, ICID, IWRA and IWSA as a basis for establishing contact with the water-user community at international level and with a view to future collaboration on specific topics such as design flood estimation in the face of climate change. It was felt that WMO and Unesco should take the lead in this respect under the auspices of WCP-Water.

D.2 Use of climate data for the study, planning and management of water resources

D.2.1 The meeting noted with satisfaction that the Unesco Source Book in Climatology for Hydrologists and Water Resource Engineers has been completed and the final manuscript was in press. The volume had been completed within the framework of IHP-III and edited by M. Sanderson with contributions from I.I. Borzenkova, M.I. Budyko, L. Kuznetsova, O. Markova, J.R. Mather, D. Nullet and A. Ohmura. The volume contains chapters on the radiation and energy balances of the Earth's surface, water in the atmosphere, the water balance of the Earth's surface and climate classification, as well as a chapter on past and future climatic change.

D.2.2 The publication of this volume within the next few weeks completes Project D.2 for the present.

D.3 Study of the impact of climatic variability and change on the occurrence of droughts

D.3.1 The technical report foreseen under IHP-Ill Project 3.4, which had been the anticipated output of Project D.3, had not been completed. The sources for preparing such a report were no longer available and the meeting was therefore pleased to learn that Mr. Beran had recently prepared a paper on the subject. It welcomed his offer to make this paper available to Unesco.

D.3.2 This completes Project D.3 for the present.

D.4 Study of the impact of climate variability and change on the occurrence of floods in urban areas

D.4.1 No activity had been executed under this project.

D.4.2 Under the auspices of Unesco, the International Research and Training Centre on Urban Drainage (IRTCUD) had recently been established in Belgrade. As Project D.4 would logically fall under IHP-IV Project M-3-3 (Integrated Water Management in Urban Areas) to which IRTCUD would also contribute, IRTCUD would be approached to assess the feasibility of this project.

D.5 Testing the transferability of hydrological simulation models

D.5.1 This project represented a call for applied research to be undertaken by national institutions.

D.5.2 It was reported that the work being undertaken by the Danish Hydraulic Institute (DHI) had been completed. A report on this work was to be issued by DHI by mid-1990 and the meeting recommended that it be widely circulated, particularly as it was the only such study known to the participants.

D.6 Impact of CO_2 induced climate change on UK water-resources

D.6.1 The meeting was informed of the work undertaken under this national project during the previous two years. This included two major desk studies, one on the effects of climatic change on quantitative aspects of UK water resources, the other on water quality aspects. Studies of impacts on flooding and on drought had also been undertaken. The report on the most recent study, that on the impact of climate variability and change on river flow regimes in Britain, was due to be issued soon.

D.6.2 Mr. Beran advised the meeting of other activities being undertaken and planned in the UK on this general subject. It was decided to maintain the project under WCP-Water and to revise its detailed description when appropriate to take account of developments at national level. In this way, the efforts of UK experts would be brought to the attention of a wide audience.

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

Work on this project was reported as being undertaken by the Swiss Federal Institute of Technology under contract to FAO. The resulting methodology was expected to be published in 1991.

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

The meeting noted that this project had moved into a more operational phase in the Sahel and expressed interest in learning in due course of the experience gained by FAO in this regard in due course.

E. Impact of climate on society through water resources

E.1 No projects were currently listed in this activity area. There was seen as being an excellent opportunity for this situation to change in next one or two years. Particular note was taken of the work of Working Groups II and III of IPCC (see 3.9 to 3.13). The subjects they were dealing with were precisely on the topic of Activity Area E and the follow-up to the publication of the IPCC Report was expected to act as a catalyst for further work in this area.

E.2 The hope was also expressed that UNEP would soon find it possible to include one or more projects under this topic.

F. Influence of man's activities on climate

F.1 Influence of Water-Resource Projects on Climate

It was reported that the proceedings of the Unesco International Symposium on the Impact of Large Water Projects on the Environment had been edited and was in press. With this action the project was considered to be completed for the present.

5. TERMINATION OF PROJECTS AND DEVELOPMENT OF NEW PROJECTS

5.1 During its review of current projects, as reported under section 4 above, the meeting recognized that certain of them had met their immediate objectives and might be considered "completed for the present". The use of this phrase was deliberate because it is always possible to do further work on any topic and under WCP-Water in particular it would be unwise to declare that a subject was ever closed. The projects identified in Annex 4 as completed could therefore be revitalised at any time in the future when concrete proposals for further work were received.

5.2 From the discussions reported under section 4, a series of proposals arose for new projects. These were either associated with activities already being undertaken under existing projects or represented entirely new ventures planned by certain groups or presented for consideration by them. These new projects are included in Annex 4 and comprise:

Project A.8	Detecting Global and Regional Runoff Trends by Monitoring Discharges of Selected Rivers
Project A.9	Monitoring Changes in the Characteristics of Extreme Hydrological Events (Floods and Droughts)
Project C.7	Development of Improved Climatic Scenarios for Water Resource Assessment
Project C.8	Verification of Probabilistic Streamflow Forecasts
Project D.9	Impact of Climate Change on the Thermal and Ice Regime of Rivers and Lakes
Project D.10	Impact of Climate Change on Suspended Sediment and Water Quality
Project D.11	Sensitivity of Storage Systems to Climate Change

5.3 The Third Phase of Unesco's International Hydrological Programme (IHP) terminated at the end of 1989. Projects A.3, B.5, D.2 and F.1 were being undertaken as part of that programme and were therefore noted as having been completed for the present.

5.4 The Fourth Phase of the IHP (IHP-IV) commenced at the start of 1990 but the detailed plans were still being drawn up at the time of the meeting. Nevertheless, in order to ensure that all Unesco activities related to WCP-Water were included, brief descriptions of the relevent IHP-IV projects are presented in Annex 5 to this report with the expectation that at the next planning meeting they would be incorporated as appropriate within the list of WCP-Water projects.

5.5 Frequent reference had been made during the meeting to work being undertaken as part of the many national global change programmes that had been launched in recent years. The set of projects described in Annex 4 to this report contains only four national projects and it was evident that many more could be included, at least in theory. It was recognized, however, that if WMO and Unesco were to mount a determined campaign to compile information on all relevant national projects, they would most probably receive a large volume of information which would be difficult to present in the current format and which would most likely be imbalanced as regards countries. It would certainly not be comprehensive. Nevertheless, it was felt that countries should once again be offered the opportunity of recording their national projects under WCP-Water so as to make them more widely known and to offer a basis for their coordination at international level. The WMO and Unesco Secretariats were therefore requested to include such an invitation in the covering letter with which the report of the current meeting would be circulated.

6. PLANS FOR THE SECOND WORLD CLIMATE CONFERENCE

6.1 The meeting was informed of plans for the Second World Climate Conference, which was scheduled to be held in Geneva from 29 October to 7 November 1990 under the sponsorship of WMO, Unesco, UNEP and ICSU.

6.2 It was noted that two reports on water-related topics would be formally presented to the Conference, these being:

Climate, Water and Development - J. Sircoulon (France)
Hydrology and Water Resource Impacts - H. Lins (USA) and 1. Shiklomanov (USSR)

6.3 A Task Group on Water would be convened to prepare a six-page contribution for the proceedings and a one-page summary and recommendations for submission to the plenary and consideration at the ministerial meetings. The latter would be held on 6 and 7 November as part of the Conference. Information was provided on the current plans for membership of this task group and participants were pleased to note that six of its 15 members were involved in the current meeting. The Task Group would be chaired by Mr. Kaczmarek. The primary documents that it would consider would be the IPCC Working Group II chapter on water resource impacts and the WCAP/WCDP report by Mr. Sircoulon. Mr. Beran would be one of the three rapporteurs.

6.4 Ministers were expected to be seeking a clear statement of the risks faced by the world community as regards its water resources and its protection from the hydrological hazards (floods and droughts) which would occur should climate forecasts of global warming be accurate. It was felt that current impact studies, by concentrating on water supply problems in humid regions, provided an incomplete view, possibly a favourable view, as insufficient attention had as yet been given to the most risk-prone parts of the world, and to problems of water quality and hazard frequency.

6.5 Hydrologists are well placed to play a key role in further studies of all three important areas - the climate system, impacts, and policy responses. The first area relates to the concern for water and energy budgets and to the part played by water in mediating biogeochemical processes. The second area, impacts, must be strengthened in order to cover a geographically and economically more diverse and relevant set of problems. The involvement of hydrologists in the third area derives from water-based energy production systems, and the long history of water projects in coping with uncertainty and the large toolkit of quantified techniques used to establish optional policy decisions in the face of uncertainty.

6.6 Finally, it was felt that the point should be pressed that water problems, even in the current climate, have not diminished in many parts of the world. With or without climate change, mankind will face serious difficulties in the years ahead. Solutions will require input from the hydrological community.

7. FUTURE DEVELOPMENTS AND MEDIUM TO LONG TERM PLANS

7.1 As reported under sections 2 and 3 above, the meeting had discussed the medium to long-term plans of WMO and Unesco. The IHP-IV was to run until 1995 and in 1991 Eleventh WMO Congress would adopt a Third Long Term Plan for the Organization that would extend to 2001.

7.2 The meeting was informed of plans for the following meetings:

- Symposium on Anthropogenic Climate Change, Hydrology and Water Resources
  - most probably in Autumn 1993 in Leningrad.

- Symposia being organised by IAHS in conjunction with the XXth IUGG General Assembly (Vienna, 11-24 August 19131)
  - in particular the Symposium on Hydrological Interactions between Atmosphere, Soil and Vegetation.

- International Workshop on Storm Surges, River Flow and Combined Effects (Hamburg, 8-12 April 1991)
  - with subsequent workshops on sea level change and the hydrological regime of coastal areas.

7.3 Finally, the participants gave some thought as to when to hold the next planning meeting on WCP-Water. It was felt that it would be useful to hold a meeting soon after the Second World Climate Conference. This would make it possible to take account of the outcome of the Conference in further defining plans for work under WCP-Water. However, if a meeting were held in about one year's time, few of the current projects would be able to report major new developments and, of more importance, the response to the outcome of the Conference by the governing bodies of the various organizations concerned would not yet be available. For example, Eleventh WMO Congress would not be held until May 1991. For these reasons, and in view of the financial limitations which precluded meeting at too frequent intervals, it was recommended that the next meeting be held in the first half of 1992. It would be hosted by WMO in Geneva unless invited by another agency or country to meet elsewhere.

8. CLOSURE

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

8.2 The participants warmly thanked Mr. Beran for the very effective manner in which he had chaired the meeting. They also expressed their gratitude to IIASA for the excellent support provided to the meeting.

8.3 The meeting closed on Friday 4 May 1990.

ANNEX 1

FIFTH PLANNING MEETING ON WORLD
CLIMATE PROGRAMME—WATER
Laxenburg, Austria, April 30—May 4, 1990

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ANNEX 2

FIFTH PLANNING MEETING
ON WORLD CLIMATE PROGRAMME-WATER

Laxenburg, 30 April - 4 May 1990

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. PLANS FOR THE SECOND WORLD CLIMATE CONFERENCE

7. FUTURE DEVELOPMENTS AND MEDIUM- TO LONG-TERM PLANS

8. CLOSURE

ANNEX 3

WORLD METEOROLOGICAL ORGANIZATION

STATEMENT ON THE HYDROLOGICAL AND WATER-RESOURCE IMPACTS OF GLOBAL CLIMATE CHANGE

This statement was drafted by Mr. M. Beran (United Kingdom) in his capacity as Rapporteur on World Climate Programme-Water of the WMO Commission for Hydrology. It was adopted by the eighth session of the Cormnission in November 1988 and was subsequently endorsed by the WMO Executive Council during its forty-first session in June 1989.

Statement on the hydrological and water-resources impacts of global climate change

(as adopted by the eighth session of the WMO Commission for Hydrology on 4 November 1988)

1. Introduction

Climates change - this much can be said without contradiction. While there is uncertainty about mechanisms and magnitudes it is at least clear that the traditional perception of a static climate is not tenable. Climatic data - the input to hydrological analyses - are themselves the output from a highly determined process driven ultimately by solar energy, but modified globally and locally by forcing agents which act on a variety of time scales. Some forcings are periodic in nature; others act through feedbacks between and within the atmosphere, the ocean, the biosphere, the cryosphere and the lithosphere. Another group, including volcanic and meteoric activity, is more sporadic and can be thought of as injecting statistical 'shocks' into the system. In a sense, the emission by man of radiatively active gases into the atmosphere can be regarded as a member of this group.

It is therefore impossible to regard climatic and hydrological series as unchanging, and it is against this background of continuous climatic variability that we must view the new risks (and conceivably benefits) of a man-induced climatic change.

2. Water-resource Impact

Water scientists are acutely aware of the multitudinous uncertainties in converting climate information to water-resource decisions due to the complexity of most practical cases and to scientific deficiencies in modelling. Given the added burden of uncertainty about climate change, it is definitely inappropriate at this time to discard available analytical procedures or to engage in expensive alterations to existing facilities. It is probable that it will be the existing end of the century before sufficient data will have accumulated and climate model results will have converged sufficiently to validate such dramatic courses of action.

However, much remains feasible and prudent despite the uncertainties that surround the climate impacts issue. Such actions relate to the encouragement of research, to environmental monitoring and data assembly, and to the informal aspects of project design and operation.

2.1. Hydrological research and monitoring

Water scientists are particularly well placed to assist in the basic data-collection and research phases of studies which are relevant to the climate change issue. In many cases hydrological agencies have been charged with the responsibility of collecting climate and hydrological data. The latter are as valuable as the former for purposes of detecting signals of change, so every encouragement should be, given to continuing measurement stations and strengthening networks. This is particularly important in areas of climatic stress, for example where evaporation and rainfall are in balance. Other hydrological data likely to be of high scientific value include those from catchments draining glaciers and from both tropical and boreal forest regions. The temperature and chemical constitution of water bodies can be as useful as physical measurements of level and flow.

Ongoing programmes should be encouraged that allow a macroscale description of hydrological processes to improve the description of land-phase processes within general circulation models (GCMs). Past and current examples of these are the Hydrological Atmospheric Pilot Experiment (HAPEX) and the International Satellite Land Surface Climatology Project (ISLSCP). Local desk and field studies, in which processes at the atmosphere and land interface, remain pertinent. Palaeohydrology links past hydrological regimes to their ambient climates. Quantification of regional floods and droughts corresponding to times of earlier warming episodes will be most useful. Quantitative geomorphology and lake ecology are associated topics that should be encouraged.

New methods of analysing site and regional assemblies of long-term records should be devised. The classical requirements of stationarity should be relaxed and hypotheses should be framed which recognize explicitly the 'wandering' nature of climatic processes. A start in this direction has been made within the WCP, in which a global hydrological data set is being assembled and its main statistical properties evaluated. Data emerging from sub-Saharan Africa provide prime opportunities for the development of realistic non-stationary models.

2.2. Water-resources research

The main difficulty in quantifying the impact on water resources of future climatic change will remain the problem of modelling the hydrological processes while simultaneously handling the complex social and economic interactions. Studies into analytical techniques for solving the problems of design and rational operation should therefore continue. However, there are problems that relate specifically to the climate change issue.

In the foreseeable future the information that will be derivable from palaeoclimatic reconstructions or from GCMs will relate to mean annual and seasonal values of primary climate variables. Water resources exist to cope with departures from mean values and spatial variability. Research is needed into techniques for bridging the disparity between what climatologists can provide and what water-resource modellers require.

Climate information, as well as being temporally inadequate, tends also to be poorly resolved spatially. For example, many GCMs work to a grid of about 300 km. The reconstitution of spatial variability on a scale of less than 100 km is another problem that needs to be incorporated into scenarios for the future. (The term “scenario” is particularly suitable for conveying the notion of plausibility and internal consistency while not being burdened by unattainable accuracy, as is implicit in the idea of a "forecast”.)

Another area needing attention is the construction of internally coherent scenarios for water demand. Past climate sensitivities might give some guidance on future demand but the effect of a sustained change would obviously give rise to a more profound adjustment. The problem is compounded by the possibility of a direct CO_2 impact on plant and crop water use.

2.3. The evaluation of water projects

As stated above, it is not appropriate to consider structural alterations to water supply facilities and projects given the uncertainty that currently surrounds the climate issue. However, there are prudent actions which should be undertaken when contemplating new schemes or reviewing the performance of existing ones. These may be encompassed in a report analogous to an Environmental Impact Statement which considers the resilience of a plan to an envisaged climate shift. For a new project such a report might consider:

(a) Evidence for non-stationarity in regional climate and hydrological data sets;
(b) Demonstration of the ability to resist hypothetical changes, perhaps constructed from the more disadvantageous periods from the historical record;
(c) Review of the overall performance of the project against more general criteria, including environmental and social impacts within the existing climate regime;
(d) The sensitivity of components of the project to first-order effects of climate change, i.e. higher temperature, reduced snowpack, glacier runoff, higher sea-levels;
(e) Informal inspection of GCM-based scenarios for 2 x CO_2 anomalies and evaluation of project design criteria if rainfall and temperature tim4; series are adjusted to agree with the revised mean values.

Items (b) and (e) explicitly consider scenarios for change. It is anticipated that (e) would be for information only whereas (b), which is based upon past variability, could be the basis for more specific action. Although no departure is envisaged from the current practice of analysing the full period of record for purposes of setting basic design parameters, there will be benefits in considering its performance against the artificially aggravated time series. Any positive findings from item (a) would be relevant here; by revealing the most sensitive aspects of the design they will allow design or operational adjustments to be made so as to optimize the source under a more severe regime. However, research is required even here in order that the aggravating assumptions are fairly stated, e.g. not sample-size dependent or unequal in the treatment of different schemes.

Item (c) reflects a conclusion, noted uniformly across all impact areas, that projects which are correctly tuned to their environment - ecologically, socially, technologically are better able to withstand the pressures of change at the margin. Similar strictures are to be read elsewhere and are already, at least in part, covered by measures such as Environmental Impact Statements.

Item (d) acts as a reminder that water-resources impacts are often linked to other impact areas. Foremost among these is the sea-level rise that will follow global warming. It is already customary to allow for a 'trend term' in sea defence work, although not necessarily tied to a specific cause. The economic and agricultural importance of coastal zones means that there is often a sea-level component to freshwater projects. Problems of saline incursion up estuaries or intrusion into aquifers may arise in future due to increases in the exploitation of these sources as well as to a rise in sea-level. Other direct impacts related to temperature may operate through changes in demand patterns for water.

3. Conclusions

Despite the many unanswered questions it is considered timely for those involved with water resources to include the certainty of variability and the possibility of change in their thinking about future water provision. The advice offered here encompasses needed research and monitoring in which water scientists play a key role. The current state of the art does not permit hard and fast rules leading to revised procedures or modified institutions and structures. Nevertheless, there is an appropriate level of response, presented here in check-list form, based upon reviewing the resilience of water resources to climate change.

ANNEX 4

WORLD CLIMATE PROGRAMME - WATER
(WCP-WATER)

ACTIVITY AREAS

AND

PRIORITY PROJECTS

As proposed by the Fifth Planning Meeting on WCP-Water
(Laxenburg, 30 April - 4 May 1990)

Summary Listing of Activity Areas and Priority Projects
for WCP-Water as prepared by the Fifth Planning
Meeting on WCP-Water
(Laxenburg, April 30-May 4, 1990)

A. STUDIES OF HYDROLOGICAL DATA IN THE CONTEXT OF CLIMATE VARIABILITY AND CHANGE

A.1 Analysing Historical Hydrological and Related Information
- IAHS with cooperation 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 cooperation with GRDC, Polish Academy of Sciences, HASA, and interested national bodies

(A.3 Distinguishing Between the Influence of Man's Activity and Climate Variability on the Hydrological Cycle)
- Project completed for the present

A.4 Monitoring of Glacier Fluctuations
- ICSI (IAHS) with the support of Unesco and UNEP

A.5 Collection of Global Runoff Data Sets
- WMO and Global Runoff Data Centre (GRDC)

(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.

A.8 Detecting Global and Regional Runoff Trends by Monitoring Discharge of Selected Rivers
- GRDC and WMO.

A.9 Monitoring Changes in the Characteristics of Extreme Hydrological Events (Floods and Droughts)
- Unesco in cooperation with WMO, HASA, GRDC and national institutions

B. MODELING OF HYDROLOGICAL CYCLE

B.1 Coupling of Physically Based Climate and Hydrological Models
- WMO and national institutions

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*Projects in parentheses have either been completed or incorporated into others and are therefore no longer being implemented.

(B.2 Development and Application of Second Generation Grid-Oriented Hydrological Modeling Techniques)
- incorporated into Project B.1

B.3 Development of Grid-Related Estimates of Hydrological Variables
- WMO and Unesco in collaboration with national institutions

B.4 Hydrological aspects of HAPEX
- National institutions, WMO and ICSU at international level

(B.5 Use of Atmospheric Moisture Transport Information for Water Balance Computations)
- Project completed for the present

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 cooperation with interested member countries.

C.4 Application of Conditional Climatological Information to Water Supply Forecasting in the USA
- US National Weather Service in cooperation with other national agencies

C.5 Reanalysis of Hydrological Observations in Czechoslovakia
- Czech Hydrometeorological Institute

C.6 Teleconnection of the El Niño Phenomenon with Extreme Hydrological Events in South America
- WMO

C.7 Development of Improved Climatic Scenarios for Water Resource Assessment
- National agencies and WMO with contributions from Unesco, HASA and IAHS.

C.8 Verification of Probabilistic Streamflow Forecasts
- US National Weather Service in cooperation with other national agencies

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, HASA and IAHS

(D.2 Use of Climate Data for the Study, Planning and Management of Water Resources)
- Project completed for the present

D.3 Study of the Impact of Climate Variability and Change on the Occurrence of Droughts
- Unesco in cooperation 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, Unesco and the International Research and Training Centre on Urban Drainage, in cooperation with WMO, IAHS and UATI

D.5 Testing the Transferability of Hydrological Simulation Models
- National institutions with international coordination by WMO

D.6 Impact of CO 2 Induced Climate Change on UK Water Resources
- Institute of Hydrology, UK, in cooperation with other national and regional bodies

D.7 Assessment of Impact of Possible Climate Change and/or Sensitivity of Irrigation Systems Including Storage of Irrigation Water in Reservoirs
- FAO in cooperation with FAO member countries

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

D.9 Impact of Climate Change on Thermal and Ice Regime of Rivers and Lakes
- Unesco and WMO in collaboration with national institutions

D.10 Impact of Climate Change on Suspended Sediment and Water Quality
- Unesco and WMO in collaboration with national institutions.

D.11 Sensitivity of Storage Systems to Climate Change
- IASA in cooperation with national research institutions

E. IMPACT OF CLIMATE ON SOCIETY THROUGH WATER RESOURCES
- No projects proposed at this stage

F. INFLUENCE OF MAN'S ACTIVITIES ON CLIMATE

(F.1 Influence on Water-Resource Projects on Climate)
- Project completed for the present

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 Analysing 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 coordination 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 methdologies 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

Circular letters have been sent out by WMO and IAHS to collect information as **a** basis for **a** review of the availability of historical hydrological and related information in member countries. Informations obtained has been included in INFOCLIMA. Three WMO-RA VI-WGH-rappoteurs, compiled relevant material available from Europe. Two IAHS-rapporteurs have been appointed.

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;
  - (ii) 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) Approach well known scientists active on the theme to seek additional material
(b) Continuation by IAHS rapporteur of compilation of inventories and studies of hydrological historical sources and field data;
(c) Continuation by IAHS rapporteur of preparation of guidance material on the analysis of hydrological information from historical records and field data.
(d) Coordination meeting between projects A.1, A.2, A.3 and A.4.

5. Organizations/bodies involved

IAHS responsible with cooperation from Unesco, WMO, ICSU and other interested international bodies and national institutions.

6. Tentative time schedule

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

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

7. Comments

This project involves the cooperation 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, exceedance of thresholds or falling below thresholds 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 analyzing 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 change.

3. Past activities

During the first stage of the project a method for analyzing long-time series including a relevant computer program was developed (WMO, WCAP Report No. 3 (WMO/TD No. 224)), and it was circulated among Member countries of WMO inviting their national institutes which collect and analyze hydrological or climatological data to participate in the project. As a first step, it was requested that such institutes be identified together with an indication as to which data sets they wish to have included in the analysis and to which degree they wish to participate in analyzing their data. As a result, a total of 58 institutes from 50 WMO Members expressed their interest in the study, making available for analysis almost 500 hydrological time series from various regions of the globe.

On the basis of discussions of experts on the occasion of the WMO Conference on Climate and Water (Helsinki, September 1989), further proposals for the implementation of the project were developed and more than 150 of the time series of hydrological data received were sent to the Global Runoff Data Centre (GRDC) for entering into a computerized data base. These were then forwarded to the Polish Academy of Sciences for analysis.

4. Further implementation

The next phases of the project will be:

Phase A - Compilation phase

(a) The data series as received from national institutions will be entered into a computer and a WCP-Water Project A.2 data base will be compiled at the Global Runoff Data Centre (GRDC) in Koblenz, FRG, with the aid of the system routinely used by Bundesanstalt fuer Gewasserkunde (BfG), Koblenz;

(b) This data base (Data Base A) will be made available to all interested institutions;
(c) Phase A will continue over an extended period so that all data received will be entered into Data Base A as and when received. The data base will therefore be up-dated from time to time and will need to be annotated as to the month and year of its latest update.

Phase B - Analysis phase

(a) All the results of analyses using the project methodology will be entered into Data Base B which will comprise: (i) the results of the analyses as provided by national institutions, where the results only, without corresponding data series, were submitted by suppliers, (ii) the results of independent analyses of data series agreed with the data supplier, where both the results and data were submitted; (iii) the results of independent analyses of the data series undertaken by the Polish Academy of Sciences, where the data only were submitted to the Secretariat;
(b) Entries in Data Base B will be annotated as to their origin and kept by the GRDC. Data Bases A and B can then be made available to all interested institutions either singly or together, including to Working Groups on Hydrology of the WMO Regional Associations;
(c) The length of time over which Phase B extends will correspond with the length of the period of Phase A.

Phase C - Interpretation phase

(a) In parallel with the implementation of Phases A and B, all participating institutions will be invited to develop proposals as to:
    (i) techniques and hypotheses for stochastic and time series modelling for use in the interpretation of the apparent variability and change in respect to time;
    (ii) the principal statistics to be used in studying variability and change with respect to space - it being recognized as infeasible to use the full set of results of Phase B for this purpose;
    (iii) how the areal study might be conducted and how its result might be displayed;
(b) A workshop is planned early in this phase to discuss (a) (i) and (ii) above in the light of the early results from Phase B. The timing of the workshop will therefore depend on progress with Phase B. Decisions can be made at the workshop as to which institution(s) will take the lead in Phase C;
(c) It is foreseen that regional analysis will play an important part in Phase C and that the Working Groups on Hydrology of the WMO Regional Associations will be involved in such work.

CHy report

In addition to the above, a report on the subject is being prepared by the CHy Rapporteur on Operational Hydrology and Climate Change.

5. Organizations/bodies involved

The project is being executed by WMO in co-operation with GRDC, Polish Academy of Sciences and IIASA and with the participation of those Member countries which have available long hydrological time series.

6. Tentative time schedule
Based on 4 above:

Phase A	1990s
Phase B	1990s
Phase C	1991-1994
CHy report	1990-1992

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 had to be identified using long time series of hydrological and climatic data, statistical methods, models and experimental data.

2. Output

A report on the "Methodology for distinguishing between the effects of man's influence and climatic effects on the hydrological cycle" by J.C. Refsgaard, W.M. Allen, and V.S. Vuglinsky has been published by Unesco (IHP-111, Project 6.3).

This project is completed for the present.

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 completed 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) Records 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 Swiss Federal Institute of Technology (ETH) in Ziirich, 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 Ziirich, Switzerland, furnishes the infrastructure of the secretariat;

(c) National institutions as correspondents.

6. Tentative time schedule

1990-1991 Completion and publication of the World Atlas of Snow and Ice Resources (IHP-IV Projects H-4-1 and H-4-2)

1990-1991 Publication of Volume VI of 'Fluctuations of Glaciers" (1980-1985)

7. Comments

Liaison with Project A.l.

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 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 km2) each representative of a hydrologically homogeneous region within the grid meshes. Monthly runoff data from large rivers are needed for several purposes. These data sets, once assembled, will also be of great value for a number of purposes in addition to the study and development of AGCMS.

2. Output

(a) Global data base for surface water runoff from about 5000 selected stations; daily and/or monthly values;
(b) Support for the development of AGCMS;
(c) Service to other activities requiring such data.
(d) Annual reports of GRDC

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) Inclusion in the GRDC of the monthly data up to 1979 published by Unesco in the 'Discharges of Selected Rivers of the World';
(d) Inclusion in GRDC of data from other sources (yearbooks, etc.)
(e) Co-operation of the GRDC with the recently established Global Precipitation Climatology Centre (GPCC) in Offenbach, FRG;
(f) Workshop on the Global Runoff Data Set and Grid Estimation (Koblenz, FRG, 10-15 November 1988) (WCRP Report No. 22 (WMO/TD-No. 302), 1989);
(g) Preparation of leaflet on GRDC.

4. Further implementation

(a) Collection of runoff data for 1978-1988 and subsequent years;
(b) Collection of additional runoff data to achieve better spatial distribution of stations;
(c) Processing and storage of data in GRDC;
(d) Compilation of information on stations;
(e) Further digitizing of catchment boundaries;
(f) Maintenance of data centre and updating the data base,
(g) Continuation of inclusion of additional data from other sources;
(h) Further co-operation with the GPCC and other relevant global data centres (e.g. GRID of UNEP).

5. Organizations/bodies involved
Based on **(a)** to (e) of 4 above:
(a) and (b): WMO Secretariat;
(c) to (h): GRDC at Federal Institute of Hydrology, Koblenz, Federal Republic of Germany, advised by GRDC Steering Committee.

6. Tentative time schedule
Continuing activity.

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 Ziirich has initiated the work of collecting directly measured energy balance fluxes and compiling 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 ultra-violet 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 1500 publications and summarized as monthly means of energy balance components at 1300 locations. Among these there are 135 stations with more than one year period of measurement. The data base scheme has been designed and a data entry application program, including “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, especially for the period prior to the time covered by WRDC/Leningrad (1964).
(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 Tehnology (ETH): Building and updating the archive from 1985 and continuing after 1990.
World Radiation Data Centre, Leningrad
NASA Longley Research Centre, Hampton
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 1990
(b) 1988-1990
(c) on continuous basis after 1991
(d) 1989-1991
(e) end 1992

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

Project A.8 Detecting Global and Regional Runoff Trends by Monitoring Discharges of Selected Rivers

1. Background

It is expected that changes in climate will affect the river runoff regime. Therefore it is important to review on a regular basis updated time series of runoff from selected rivers. For this reason runoff data should be collected from suitable stations on a routine basis soon after they are observed. Stations for this purpose should be selected on the basis of the following criteria:

(a) Stations nearest the coast on the 15 largest rivers of the world to monitor the main inflow into the oceans,

(b) 30 additional stations with long records and reliable data, equally distributed over the whole world, to monitor change.

2. Output

(a) Results will be published regularly

(b) Early recognition of possible changes to draw the attention of decision makers on the effects.

3. Past activities

Project developed from past activities under Projects A.2, A.3 and A.5.

4. Further implementation

(a) Selection of suitable stations

(b) Routine collection of runoff data

(c) Inclusion of the runoff data in the GRDC

(d) Regular analysis of data to monitor inflow to the oceans and possible change

(e) Regular publication

5. Organizations/bodies involved

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

(a) GRDC and WMO Secretariat, in consultation with Members concerned

(b) WMO Secretariat

(c) GRDC

(d) and (e) GRDC with other institutions interested in the subject.

6. Tentative time schedule

(a) 1990

(b) 1990-1991

(c) to (e) Continuing activity

7. Comments

Liaison with projects A.2 and A.5.

Project A.9 Monitoring Changes in the Characteristics of Extreme Hydrological Events (Floods and Droughts)

1. Background

It is expected that as a result of the greenhouse effect the frequency and intensity of floods and droughts may change. Due to some very severe events in recent years the impression has been obtained that changes have already occurred. However up to now there has been no systematic approach to the collection of relevant data or their statistical analysis. Therefore this project aims to develop approaches to the problem of detecting changes in the statistical characteristics of extreme hydrological events.

In the first step of the project available data on floods and droughts should be collected, updated and unified. The initial analysis should be made by existing simple empirical methods. Later on in the project the necessary methods for statistical analysis for comprehensive studies should be developed which recognise the existence of nonstationarity.

2. Output

(a) Improvement of knowledge with respect to the effects of climate change on the statistical characteristics of hydrological events both as regards their magnitudes and their frequencies of occurrence.

(b) Early recognition of possible changes to allow decision makers to undertake appropriate steps.

3. Past activities

Publication of:

- Discharge of Selected Rivers of the World, Volumes I, II and III, Studies and Reports in Hydrology No. 5, Unesco, 1971 et seq.
- World Catalogue of Maximum Observed Floods by J. Rodier and M. Roche, IAHS Publ. No. 143, 1984
- Hydrological Aspects of Drought by M. Beran and J. Rodier, Studies and Reports in Hydrology No. 39, Unesco and WMO, 1985
- Methodology for Distinguishing between Man's Influence and Climatic Effects on the Hydrological Cycle by J. Refsgaard, W. Alley and V. Vuglinsky, Technical Documents in Hydrology, Unesco, 1989.

4. Further implementation

(a) Compilation of relevant hydrological data; i.e. updating flood catalogue and creating equivalent information on droughts.

(b) Inclusion of data in GRDC

(c) Standardization of the material available

(d) Analysis of the data and interpretation of results

(e) Workshop to plan future statistical analyses

5. Organization/bodies involved

The project is to be executed by Unesco within the framework of IHP-Project H-2-3 in cooperation with WMO, HASA, GRDC and national institutions.

6. Tentative time schedule

(a) 1990-1991
(b) 1991-1992
(c) 1992-1993
(d) and (e) 1993

7. Comments

Liaison with Projects A.2, A.3, A.5 and A.8.

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 1.5 to 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-oriented 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. This project is therefore seen as providing direct support to the WMO Global Energy and Water Cycle Experiment (GEWEX).

2. Output

Presentation of practical ways for bringing together results of physical climate and hydrological modelling in order to accommodate the physically based relationships (feed-backs) 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 meetings, Messrs. Becker and Nemec 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. Nemec, 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.

Proposals for work on macro-scale modelling in support of the Global Energy and Water Cycle Experiment (GEWEX) were developed by the IAHS/WMO Working Group for GEWEX (St. Moritz, December 1989).

These proposals subsequently became part of the GEWEX Continental Scale Study which is expected to be implemented first in the USA, centered on the Mississippi Basin.

4. Further implementation

(a) Preparation of a report on macro-scale hydrology - by the CHy Rapporteur on Hydrological Modelling for Climate Studies;

(b) Preparation of a report on the potential interaction between climate and hydrological processes at the land surface - by the CHy Rapporteurs on Hydrological Interactions of the Land Surface;

(c) Further development of plans for GEWEX, in particular the Continental-scale Project.
(d) Initiation by IIASA of a project on macroscale hydrological models.

5. Organizations/bodies involved

WMO, as lead agency under GEWEX, the WMO Commission for Hydrology and national institutions.

6. Tentative time schedule

1990-1992 for 4 (a) and (b) above
1990-2000 and beyond for 4 (c) above.

7. Comments

Liaison with A.5, A.7 and B.3.

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. This project is seen as providing direct support to the WMO Global Energy and Water Cycle Experiment (GEWEX).

2. Output

(a) A methodology and generalized procedure for the transfer of hydrological information, as well as physiographic and other characteristics to grid point or grid ara values;

(b) One or more such methodologies for use in treating the data held by the WMO Global Runoff Data Centre (GRDC).

3. Past activities

(a) A state-of-the-art report on grid-point and grid-area estimates was prepared as a draft and reviewed at the Workshop on the Global Runoff Data Set and Grid Estimation (Koblenz, FRG, 10-15 November 1988) (WCRP Report No. 22 (WMO/TD-No. 302), 1989);

(b) Preliminary plans for the compilation of gridded sets of runoff and related data were prepared at the second meeting of the IAHS/WMO Working Group for GEWEX (St. Moritz, December 1989);

(c) The plans were subsequently developed and became parts of two related, but independent projects:

  (i) GEWEX Continental Scale Study expected to be implemented first in the USA, centered on the Mississippi Basin

  (ii) Project for Gridded Estimates of Runoff over Central Europe to be coordinated by WMO and involving Austria, Czechoslovakia, FRG, GDR, Hungary, Poland and Switzerland and a third activity arising out of the Unesco FRIEND project:

  (iii) Characterization of Large Scale Variations in River Flow Behaviour in Europe to be coordinated by the Advisory Group for FRIEND and covering the west and north-west of Europe;

(d) Proposals for (c) (i) were adopted at the meeting of the Joint Scientific Committee for the WCRP (Tokyo, March 1990) for inclusion in the Scientific Plan for GEWEX;

(e) Plans for (c) (ii) were developed at the Planning Meeting on Grid Estimation of Runoff Data (Laxenburg, March 1990);

(f) Plans for (c) (iii) were approved at the second meeting of the Advisory Working Group for FRIEND (Paris, March 1990).

4. Further implementation

(a) Finalization and publication of the report referred to under 3(a);

(b) Further development of detailed plans for project (c) (i), in particular in conjunction with national agencies concerned;

(c) Phase I of project (c) (ii) sees participating institutions testing methodologies. Phase 11 includes a pilot exchange of data and Phase III should result in the uniform applications of agreed methodologies. A meeting of participating institutions is planned for May 1991 in Laxenburg;

(d) Detailed plans for Project (c) (iii) will be drawn up in 19W.

5. Organizations/bodies involved

WMO in collaboration with national institutions for projects 3 (c) (i) and (ii) and with contributions from IIASA

Unesco in collaboration with national institutions for Project 3 (c) (iii).

6. Tentative time schedule

1990-2000 and beyond for project 3 (c) (i)
1990-1995 for project 3 (c) (ii)
1990-1995 for project 3 (c) (iii).

7. Comments

Liaison with Projects A.5 and B.I.

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.

4. Further implementation

(a) HAPEX Experiment in Niger, 1992;
(b) European Field Experiment in a Desertification Threatened Area (EFEDA), Spain, 1994 (preliminary test 1991);
(c) Second ISLSCP Field Experiment (SIFE), Canada, 1994;
(d) Storm Central experiment, Central Great Plains, USA, 1990s;
(e) Land surface processes/hydrology experiments;
(f) Collation and storage of HAPEX data sets;
(g) Distribution of the data sets.

5. Organizations/bodies involved

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

6. Tentative time schedule

Continuing, each experiment having its own time schedule.

7. 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) Publication 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" (IHP-III/1.1 Technical Documents in Hydrology, Paris, 1989) by L.P. Kuznetsova.

(b) Increased knowledge about the possibilities of using aerological methods for linking surface hydrological and climatic knowledge in the framework of climate change studies.

This project is completed for the present.

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 the CHy Rapporteur on WCP-Water

6. Tentative time schedule

1990-1991 Continued accumulation of material
1991-1992 Preparation of report.

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 actor 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 Comit6 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 Co-operation 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 1:5,000,000 was published in 1987. The publication is available on request.

4. Further implementation

The methodology to be used in this project is subject to re-assessment in the light of available data and new technological possibilities. Digitization of soil maps at the 1 to 1 million scale is in progress.

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

The Water Service in the FAO Land and Water Division is performing the work with the co-operation of countries in the Nile Basin belonging to IGADD:

6. Tentative time schedule

The first phase was terminated in 1987; the 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.

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;

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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.

(f) Prepare final report.

5. Organizations/bodies involved

The principal organization involved in this project will be the US National Weather Service in co-operation 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 of water resources and call for a re-analysis of the existing hydrological records.

2. Output

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

3. Past activities

On the basis of a pilot study which was finalized in 1988, the work continued on the selection and application of suitable methodologies for evaluating hydrometeorological data and information for each of the following parts of the project:

(a) Analysis of long-term hydrometeorological series:
The homogeneity and stationarity studies of selected data series with observations for more than 80 years were carried out;
(b) Re-analysis of hydrometeorological characteristics:
A new method for estimating daily discharges of given duration and peak flows of given return period (N-year events) was developed. The method makes use of the results of a study of discharge characteristics at streamgauging stations and their regional estimates and takes into consideration the interdependence of discharge characteristics in the streamgauging network of a river system;
(c) Changes in water balance:
Various techniques for water-balance studies were verified and the work continued on the preparation of input data and information, as well as methods for the evaluation of potential changes in the runoff resulting from climate variability and change.

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) Comprehensive data processing;
(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 (c) of (2) above:
(a) 1989-1994;
(b) started 1986 and continuing;
(c) 1994.

7. Comments
This project will be closely coordinated with Projects A.2 and D.I.

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) Selection of catchments and methodologies to be applied and assembling of both meteorological (El Niño) and hydrological (catchment) data;
(b) Analysis (modelling, correlations, etc.);
(c) Reporting on the results of the study.

3. Past activities

A survey was initiated in 1989 among WMO Member countries of Regional Association III (South America). The survey sought information on hydrological aspects of the ”El Niño” phenomenon, geared to the establishment of a common methodological base that would allow the evaluation of the hydrological repercussions of the phenomenon, with the aim of forecasting and mitigating its negative effects such as floods and droughts.

4. Further implementation

The material collected through the above survey will be analyzed 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

Based on (a) to (c) under (2) above:
(a) 1990
(b) 1990-1993
(c) 1993.

7. Comments

Liaison with Project D.I.

Project C.7 Development of Improved Climatic Scenarios for Water-Resource Assessment

1. Background

Perhaps the single most significant of all the effects of global climate change is the effect on the availability of water. Water-resources managers need to have methods for assessing the sensitivity of the systems they manage to changes in climate, CO_2 concentrations, and sea level. Also of importance is the need for methods of evaluating the risk or uncertainty associated with such assessments. Many of the existing predictive tools (watershed models) are not sufficiently focused on the water and energy balance issues to provide the necessary answers. Virtually all techniques of hydrologic analysis are based on the assumption of a stationary or unchanging climate. Present means of generating the meteorological forcing functions for hydrologic models under assumptions of climatic change use simple adjustments to current climatic conditions. Development of methods which make full use of information from general circulation models (GCMS) and observational data to drive hydrological models is envisioned.

2. Output

(a) Transferable methods for translating generalized, synoptic-scale climate model out-put into a hydrologically-relevant stream.

(b) Application and comparison of methods in terms of water-resource planning and policymaking in order to assess the risk or uncertainty of assessments.

3. Past activities

Methodological studies and sensitivity analyses have begun as part of the US Global Change Research Program. National studies concerning the use of weather types and other methods of deriving hydrological model inputs from GCM output.

4. Further implementation

National studies within the context of follow-up to the publication of the IPCC report in 1990.

5. Organizations/bodies involved

National agencies with international coordination by WMO, with contributions from Unesco, IIASA and IAHS. USGS is currently undertaking such studies as part of the US Global Change Research Program.

6. Tentative time schedule

Ongoing through 1990s.

7. Comments

Liaison with Projects D.1, D.2 And B.1.

Project C.8 Verification of Probabilistic Streamflow Forecasts

1. Background

Forecasts of future streamflow events are beginning to be made in terms of estimated conditional distributions of the events. These forecasts are most useful for the distant future where there is usually much uncertainty. Long-term forecasts of seasonal snowmelt runoff have been made since the 1930's using regression models. Since the mid 1970's, conceptual hydrologic models have been used together with historical climatological data to make "Extended Streamflow Predictions," not only of the seasonal snowmelt runoff volume, but specific attributes such as maximum or minimum stages, durations of events, etc. Their application to low flow and reservoir inflow forecasting during droughts has emerged during the last 10 years.

This study will investigate how to judge the performance of these techniques. Are probabilistic forecasts from conceptual models likely to be biased? Is there actually more uncertainty than these models indicate? How well do these models perform as compared to simpler statistical methods? If conceptual models lead to biased probabilistic forecasts, can the biases be corrected while preserving the skill of the model? Does including positional climatological information improve forecast skill without introducing bias in the resulting probabilistic forecasts?

The proposed approach is to formulate a conceptual statistical framework which allows verification statistics to be defined and their distributions to be estimated by simulating forecasts during the historical period. These statistics would be used to address the questions raised above.

2. Output

Report on the subject of the project.

3. Past activities

This project evolved from activities being undertaken in conjunction with WCP-Water Project C.4.

4. Further implementation

National study by agencies concerned.

5. Organizations/bodies involved

US National Weather Service in cooperation with other water-related organizations in the USA.

6. Tentative time schedule

Report should be available in 1993.

ACTIVITY AREA D

STUDIES OF THE INFLUENCE OF CLIMATE CHANGE AND VARIATION ON 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 cause 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 change and variation 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 and semi-arid regions where variability, for example in annual runoff, is already high so that stable water-resource schemes to compensate for the uncertainty and shortages of supplies are 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) Am increase in our application of the performance of different hydrological modelling techniques in replicating the response to climate inputs;
(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.l. 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. 4,1988;
(c) Material prepared in 1988 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;
(d) WMO Statement on the Hydrological and Water-Resource Impacts of Global Climate Change - adopted by CHY-VIII in November 1988, endorsed by WMO Executive Council in June 1989;
(e) Convening by WMO of the Conference on Climate and Water (Helsinki, September 1989) - proceedings published in 1989 and report in 1990.

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.

A report on the subject is being prepared by the CHy Rapporteur on Operational Hydrology and Climate Change.

5. Organizations/bodies involved
Research at national level.
WMO at international level, with contributions from Unesco, IIASA and IAHS.

6. Tentative time schedule
Continuing long-term activity.
CHy report by 1992.

7. Comments
Closely linked with Project B.1 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 curricula for the training of water-scientists through the preparation of a source book on climatology for hydrologists and water-resource engineers.

(d) Publication of the Unesco Source Book in Climatology for Hydrologist and Water Resource Engineers edited by M. Sanderson (IHP, Paris, 1990

This project is completed for the present.

Project D.3 Study of the Impact of Climatic Variability and Change on 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 foreseen under Unesco/IHP-111 Project 3.4 was not prepared. However, a report on the drought aspects will be prepared.

5. Organizations/bodies involved

Unesco in cooperation of WMO and IAHS.

6. Time schedule

Publication of the report by Unesco in 1991.

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 over-come the hazard.

3. Past activities

None.

4. Further implementation

A related project is established under IHP-IV Project M-3-3 (Integrated water management in urban areas).

5. Organizations/bodies involved

National institutions, Unesco and the International Research and Training Centre on Urban Drainage (Belgrade) in cooperation with WMO, IAHS and UATI.

6. Tentative time schedule

Not yet 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

(a) Publication by WMO in 1985 of WCP Report No. 98 - Sensitivity of Water Resource Systems to Climate Variability;

(b) Publication 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.

Report on DHI project to be issued by mid-1990.

7. Comments

Liaison with Project D.l.

Project D.6 Impact of CO_2 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_2 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 are:

(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) Hydrograph comparison between global warm and cool periods;
(c) Literature review of climate scenarios for CO_2 doubling in the European area for mean and variance of climate variables;
(d) Estimate of low flow and reservoir reliability consequent on climate scenarios.

3. Past activities

A team has been assembled at IH to conduct the studies consisting of a hydrologist supervisor and two climatologist/statisticians 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. FREND (Unesco IHP Project 6.1). The Climate Research Unit of the University of East Anglia (Norwich, UK) has interpreted climate model results. 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. A report has been prepared containing analysis of past hydrological records and runoff impact maps.

4. Further implementation

The following topics will be studied:

(a) scenarios for changed variability
(b) use of weather types
(c) groundwater and soil moisture impacts
(d) water demand sensitivity to change
(e) estuary and river quality impacts.

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) and possibly also the Commission for European Communities.

6. Tentative time schedule
The study will last three years from April 1990.

7. Comments
Liaison with Projects A.1, A.2, A.4 and C.l.

Project D.7 Assessment of Impact of Possible Climate Change and/or Sensitivity 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. Relevant work is being carried out under subcontract by the Swiss Federal Institute of Technology, Zurich. The methodology is expected to be available in December 1990.

5. Organizations/bodies involved

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

6. Tentative time schedule

1990 Final methodology
1991 Publication.

7. Comments

This project is being implemented in conjunction with Project C.3 and D.8.

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 has been 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 have been published. Climate change would no doubt alter these projections considerably.

2. Output

Projections of the population supporting capacity of land with 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. First phase work on the impact of climate variation on population supporting capacities is in progress for the Sahel countries. Similar studies are being planned for other areas.

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 being undertaken in conjunction with Projects C.3 and D.7.

Project D.9 Impact of Climate Change on Thermal and Ice Regime of Rivers and Lakes

1. Background

Due to the change of the climatological regime, the thermal and ice regimes of rivers and lakes may change as a consequence of changes in the hydrological regime due to climate change. A proper understanding of the changes in the thermal and ice regime is also necessary for studies of water quality and of the impact on the aquatic environment. A study based on certain climate scenarios may help to derive some conclusions as regards the change in the thermal regime.

2. Output

(a) A methodology and generalized procedure for the assessment of changes in the thermal and ice regime of streams and lakes, including reservoirs.
(b) Case studies based on typical scenarios of the impact of climate change on thermal and ice regimes.
(c) Conclusions as to the order of magnitude of potential changes of water temperature, ice formation, duration of icy periods and ice thickness and on the general tendencies in these phenomena.

3. Past activities

Detailed studies on thermal and ice regimes of major rivers and lakes have been implemented, but no account has been taken of potential climatic change.

4. Further implementation

(a) Compilation of a fact finding report on the status of methodologies available for the impact studies
(b) Detailed plans for selected case studies to be implemented by methods selected on the basis of (a)
(c) Implementation of case studies
(d) Workshop based mostly on the case studies
(e) Final report on the conclusions related to the assessment of changes in thermal and ice regime.

5. Organizations involved

Unesco and WMO in collaboration with interested national institutions, particularly for (c).

6. Tentative time schedule

1991-92 for (a) and (b)
1992-93 for (c)
1993 workshop (d)
1994 final report (e)

7. Comments

Liaison with Projects C.7, D.1 and D.10.

Project D.10 Impact of Climate Change on Suspended Sediment and Water Quality

1. Background

Any change in the hydrological regime may influence suspended sediment concentrations, the temperature of water and its hydrochemical and hydrobiological indices. A decrease in the minimum flow changes the dilution rate of pollutants and a change in flow velocity may influence sediment concentration. While some efforts have been successful in detecting changes in the water regime, almost no reference can be found on the potential change in sediment and water quality. Global warming may influence the thermal regime of rivers and lakes, which has an impact on aquatic life, including benthos and algae. A study based on certain climate scenarios may contribute to the understanding of potential influences on water quality.

2. Output

(a) A methodology and generalized procedure for the assessment of changes in the sediment and water quality regime of streams and lakes.
(b) Case studies based on typical scenarios of climatic change on suspended sediment and water quality regimes.
(c) Conclusions as to the order of magnitude of potential changes of major parameters and as to general tendencies.

3. Past activities

Relatively little consideration has been given to these secondary effects of climate change. Some information can be found in the papers of the WMO Conference on Climate and Water (Helsinki, 11-15 September 1989), particularly in the papers by M. Beran and M. Falkenmark.

4. Further implementation

(a) Compilation of a fact finding report on the status of methodologies available for the impact studies
(b) Detailed plans for selected case studies to be implemented by methods based on the report under (a)
(c) Implementation of case studies
(d) Workshop mostly based on the methods and the case studies
(e) Final report on the conclusions related to assessment of changes in sediment and water quality regimes.

Activities related to these problems are also likely to be undertaken as part of IGBP.

5. Organizations involved

Unesco and WMO in collaboration with interested national institutions.

6. Tentative time schedule
   1991-92 for (a) and (b)
   1992-93 for (c)
   1993 workshop (d)
   1994 final report (e)

7. Comments
   Liaison with Projects C.7, D.2 and D.9.

Project D.11 Sensitivity of Storage Systems to Climate Change

1. Background

Storage reservoirs are efficient tools for coping with hydrological variability and for ensuring the necessary reliability of meeting various water demands. Because of their cumulative effects on both natural and man-made storage systems, any changes in climatic and hydrological variables may be seriously magnified when they are transferred into changes of storage characteristics. Such changes might be reflected in the performance criteria of water-resource systems based on the operation of storage reservoirs. This project addresses directly the possible impact of climatic and hydrological nonstationarity on the design and operation of water storage systems.

2. Output

(a) Methodology for evaluating possible consequences of climatic change on reliability, resilience and robustness of water storage systems.

(b) Policy suggestions in the face of uncertainty linked with the estimation of future climatic conditions of storage behaviour.

3. Past activity

A number of scientific papers have been published in connection with the possible impact of climatic change and storage systems. However, no systematic and comprehensive review of the problem is available.

4. Further implementation

(a) Development of **a** general methodology that may be used by water-resource planners in dealing with the design and operation of storage systems.

(b) Case studies and analyses for selected regions of the world.

5. Organization

IIASA's Water Resources Project, in cooperation with interested national research institutions.

6. Tentative time schedule

1990-91 development of methodology and elaboration of one or two pilot case studies.
1992-93 Other case studies and final report (monograph).

7. Comments

This project will be implemented in conjunction with D.1 and 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 or 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.

ACTIVITY AREA F

INFLUENCE OF MAN'S ACTIVITIES ON CLI[MATE

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, 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.

3. Past activities

The Symposium mentioned under 2(d) took place. The Proceedings have been edited and will be published in 1990.

This project is completed for the present.

ANNEX5

WCP-WATER RELATED PROJECTS

OF THE FOURTH PHASE OF UNESCO'S

INTERNATIONAL HYDROLOGICAL PROGRAMME

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

Background

The interaction and interface processes between the various hydrological subsystems form the essential transport mechanisms of the hydrological cycle. The atmospheric and land surface subsystems are coupled through the physical processes of energy and moisture exchange at the land-atmosphere interface. Major uncertainties in this part of the hydrological cycle include the role of the vegetation, land-use practices and ecological processes with respect to the energy, moisture and momentum fluxes and of their modification in changing climatic situations. Special attention will be given to physical description, parameterization and generalization of the interface processes at different scales (elementary plot, catchment, models grids). Erosion of the watershed and river bed deformation processes are also essential to a thorough understanding.

Objectives

(a) To improve knowledge of interface processes of water in the atmosphere-vegetation-soil system and to investigate how these processes can be most appropriately described at various time and spatial scales.

(b) To review the methods to describe the erosion process, the sediment transport and the river-bed deformations in particular with respect to natural and man-made changes of the environment.

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

Objectives

To highlight new developments in physical description of the water transport through the atmosphere-vegetation-soil system with emphasis on evapotranspiration, infiltration and soil moisture dynamics and the spatial and temporal variability of input, output and parameter fields. Due attention will be given to the verification of model results and the scientific basis of parameter generalization from the elementary scale to a catchment and grid size scale: the importance of data obtained from remote sensing and nuclear techniques will also be reviewed.

Project H-1-2: Study of erosion, river bed deformation and sediment transport in river basins as related to natural and man-made changes.

Objectives

To generalize the international experience in the study of erosion, river bed deformations and sediment transport with particular reference to natural and man-made changes in the environment (especially climatic changes).

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

Background

Due to anthropogenic increases in greenhouse gasses in the atmosphere, global average temperatures may rise substantially in the future. This possible increase in temperature would effect the hydrological cycle greatly. Since the WMO World Climate Conference in 1979, the water-related aspects of the World Climate Programme are being coordinated jointly by the water divisions of WMO and Unesco.

Objectives

(a) To study the impacts of climate variability and change in order to increase the possibilities of making hydrological and water resources predictions.

(b) To transfer knowledge from the meteorological and climatological community to hydrologists and water resources engineers to improve hydrological techniques.

Project H-2-1: Study of the relationship between climate variability (and expected changes) and hydrologic regimes affecting water balance components.

Objectives

To determine expected changes in water balance components of large regions including change in the runoff distribution on the basis of available trends and climate change scenarios taking into account related changes in vegetation, including different climatic zones and physiographic regions.

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

Objectives

To study the hydrologic and water management problems and hazards of surface and groundwater regimes (qualitative and quantitative) of low lying coastal regions and deltaic areas, resulting from exogeneous influences and possible sea level changes.

Project H-2-3: Extraordinary rainfall and snowmelt floods in rivers of the world

Objectives

To document extreme and extraordinary floods of the world, to characterize spatial and time distribution and to explain their origin according to the different factors involved, including climatic and man-made and natural environmental factors.

Theme H-4: The role of snow and ice in the global water cycle

Background

The study of snow and ice hydrology and of glaciers is important for water resources assessment and management. An understanding of large-scale snow and ice covers, seasonal or permanent interaction with the global and regional climate and thus precipitation systems are also of importance. A better documentation of their extent both at present and in the past, as well as of temporal and areal variations of snow and ice cover characteristics under anthropogenic environmental influence is of increasing importance for the understanding and prediction of possible climate variability and change.

Objectives

(a) To increase the understanding of the basic physical processes and the role snow and ice play in the hydrological cycle, at local levels as well as at continental and global levels;
(b) To compile and disseminate knowledge about the hydrology of mountainous snow and ice;
(c) To study temporal and areal variations of snow and ice cover characteristics under anthropogenic environmental influence.

Project H-4-1: The effect of large-scale snow and ice covers on global and regional precipitation systems.

Objectives

To study the relationship between snow, ice covers and ice sheet dynamics and global and regional precipitation patterns using global and meso-scale circulation models.

Project H-4-2: Snow and ice hydrology in specific areas and regions with special attention to long-term variations in water storage.

Objectives

To compile existing knowledge on snow and ice hydrology of specific areas and to provide methodological guidelines for further studies in different climatic regions of the world.

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 CHANGEs SENSITIVITY OF WATER-RESOURCE SYSTEMS TO CLIMATE CHAIUE AND VARIABILITY. Norwich, U.K., November 1987

WCAP - 5 FOURTH PLANNING MEETING ON WORLD CLIMATE PROGRAMME - WATER. Paris, 12-16 September 1988

WCAP - 6 CLIMATE APPLICATIONST ON USER REQUIREMENTS AND NEED FOR DEVELOPMENT [Reports of the CC1 rapporteurs on Users' Requirements and Publicity (F. Singleton) and New Approaches in Applications (D.W. Philips) to the tenth session of the Commission for Climatology, Lisbon, April 19891

WCAP 7 DROUGHT AND DESERTIFICATION. [Report of the CC1 Rapporteur on Drought and Desertification in Warm Climates to the tenth session of the Commission for Climatology (Lisbon, April 1989) (L.J. Ogallo) and lectures presented at the training seminar in Mufloz, Philippines (14-24 November 1988) by N. Gbeckor-Kove]

WCAP - 8 REPORT OF THE FIRST SESSION OF THE CC1 WORKING GROUP ON CLIMATE AND URBAN AREAS INCLUDING BUILDING AND OTHER ASPECTS AND SOME RELATED PAPERS by Professors E. Jauregui and Shen iianzhu, Members of the Working Group

WCAP - 9 REPORT OF THE EXPERT MEETING ON CLICOM CLIMATE APPLICATIONS (INCLUDING CARS), Geneva, 6-10 November 1989

WCAP - 10 URBAN DESIGN IN DIFFERENT CLIMATES by B. Givoni, University of California, U.S.A.

WCAP - 11 FIFTH PIANNING MEETING ON WORLD CLIMATE PROGRAMME - WATER, Laxenburg, Austria, 30 April - 4 May 1990