...logy and Water Balance ...all Islands. A Review of Existing Knowledge

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UNITED NATIONS EDUCATIONAL
SCIENTIFIC AND CULTURAL ORGANIZATION

International Hydrological Programme

HYDROLOGY AND WATER BALANCE OF SMALL ISLANDS
A REVIEW OF EXISTING KNOWLEDGE

(IHP-III Project 4.6)

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PREFACE

Although the total amount of water on Earth is generally assumed to have remained virtually constant during recorded history, periods of flood and drought have challenged the intellect of man to have the capacity to control the water resources available to him. Currently, the rapid growth of population, together with the extension of irrigated agriculture and industrial development, are stressing the quantity and quality aspects of the natural system. Because of the increasing problems, man has begun to realize that he can no longer follow a 'use and discard' philosophy -- either with water resources or any other natural resource. As a result, the need for a consistent policy of rational management of water resources has become evident.

Rational water management, however, should be founded upon a thorough understanding of water availability and movement. Thus, as a contribution to the solution of the world's water problems, Unesco, in 1965, began the first worldwide programme of studies of the hydrological cycle -- the International Hydrological Decade (IHD). The research programme was complemented by a major effort in the field of hydrological education and training. The activities undertaken during the Decade proved to be of great interest and value to Member States. By the end of that period a majority of Unesco's Member States had formed IHD National Committees to carry out the relevant national activities and to participate in regional and international co-operation within the IHD programme. The knowledge of the world's water resources as an independent professional option and facilities for the training of hydrologists had been developed.

Conscious of the need to expand upon the efforts initiated during the International Hydrological Decade, and, following the recommendations of Member States, Unesco, in 1975, launched a new long-term intergovernmental programme, the International Hydrological Programme (IHP), to follow the Decade.

Although the IHP is basically a scientific and educational programme, Unesco has been aware from the beginning of a need to direct its activities toward the practical solutions of the world's very real water resources problems. Accordingly, and in line with the recommendations of the 1977 United Nations Water Conference, the objectives of the International Hydrological Programme have been gradually expanded in order to cover not only hydrological processes considered in interrelationship with the environment and human activities, but also the scientific aspects of multi-purpose utilization and conservation of water resources to meet the needs of economic and social development. Thus, while maintaining IHP's scientific concept, the objectives have shifted perceptibly towards a multi-disciplinary approach to the assessment, planning, and rational management of water resources.

As part of Unesco's contribution to the objectives of the IHP, two publication series are issued: 'Studies and Reports in Hydrology' and 'Technical Papers in Hydrology'. In addition to these publications, and in order to expedite exchange of information, some works are issued in the form of Technical Documents.

HYDROLOGY AND WATER BALANCE OF SMALL ISLANDS
A REVIEW OF EXISTING KNOWLEDGE

LIST OF CONTENTS

LIST OF ACRONYMS

CARDI	Caribbean Agricultural Research and Development Institute
CDB	Caribbean Development Bank
CIDA	Canadian International Development Agency
COHI	Caribbean Operational Hydrology Institute
ECA	Economic Commission for Africa
ECE	Economic Commission for Europe
ECLA	Economic Commission for Latin America
ECWA	Economic Commission for Western Asia
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GERSAR	Groupement d'etudes et realisations des societes d'amenagement regional
HIMAT	Instituto Colombiano de Hidrologia, Meteorologia y Adecuacion de Tierras
IAH	International Association of Hydrogeologists
IHP	International Hydrological Programme
IMPOISLAS	Empresa de Acueducto y Alcantarillado de las Islas de San Andres y Providencia
MAB	Man and Biosphere Programme
OAS	Organization of American States
OPEC	Organization for Petroleum Exporting Countries
PNUD	United Nations Development Programme (UNDP) in French
ROSTA	Regional Office for Science and Technology for Africa
ROSTSCA	Regional Office for Science and Technology for South and Central Asia
ROSTLAC	Regional Office for Science and Technology for Latin America & the Caribbean
ROSTSEA	Regional Office for Science and Technology for Southeast Asia
UN.DTCD	Department of Technical Co-operation for Development of the United Nations
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
WHO	World Health Organization
WMO	World Meteorological Organization

1. INTRODUCTION

When evaluating the results of the International Hydrological Programme (IHP) at the International Conference on Hydrology and the Scientific Bases for the Rational Management of Water Resources (Paris, 18-27 August 1981), the participants considered that in spite of the success obtained to date in many fields, there were still gaps in certain specific subjects. In this regard, it recommended to Unesco the implementation of a project dealing with the hydrology of small islands.

At its the Sixth Session, the Intergovernmental Council of the IHP (Paris, 22-30 March 1984) approved the activities to be undertaken during the Third Phase of the IHP (1984-1989). The overall title of the third phase of the IHP is "Hydrology and the Scientific Bases for the Rational Management of Water Resources for Economic and Social Development". The plan is broadly based, having regard to the varying needs of the developed and developing countries and the fact that the execution of IHP activities in Member States is and will be based on their specific social, economic and cultural patterns. Emphasis is given to the specific problems of particular regions and land areas.

The plan of Phase III identifies eighteen themes which have been grouped under four main sections. Section I deals with hydrological processes and parameters for water projects, and includes Theme 4 - Hydrology of particular regions and land area , and under this Theme, Project 4.6 refers specifically to the hydrology of small islands.

At its twelfth session (22-25 October 1984) the IHP Bureau appointed the raporteurs of IHP-III Project 4.6 and at its thirteenth session (2-4 December 1985) confirmed Mr. Andres Diaz Arenas as Principal Rapporteur and Mr. Jose Febrillet Huertas as Co-rapporteur.

The International Association of Hydrogeologists (IAH), the Water Research Branch of the Division of Natural Resources and Energy, Department of Technical Co-operation for Development of the United Nations (UN-DTCD), the Council of Europe and several IHP National Committees expressed their interest in co-operating with this project. Messrs. E. Custodio (IAH), Robert Dijon (UN-DTCD), L. Simler (Council of Europe) and A. Falkland, T. Chapman and T. Daniell (Australia) were indicated as Correspondents.

Mr. Nelson da Franca, Programme Specialist of the Division of Water Sciences of Unesco was the responsible person within the IHP Secretariat for the Project with the collaboration of Unesco Regional hydrologists: Messrs. J. Urban (ROSTSEA), L. Mandalia (ROSTSCA) and K.A. Tuffuor (ROSTA).

In accordance with recommendations of the IHP Bureau, the work of IHP-III Project 4.6 was carried out mainly by correspondence. In 24-28 February 1986 the rapporteurs met at Unesco Headquarters, in Paris, to prepare the present report, based on the material received.

2. SCOPE OF THE REPORT

Small islands have special problems of their own, resulting from their particular physical features. Lack of land space and the scarcity of some natural resources, such as fresh water, minerals or energy imply economical problems and necessitate the development of new approaches in the assessment, development and use of water resources. The availability of fresh water on small islands is frequently critical because it is dependant upon the temporal and areal distribution of precipitation and on the storage potential above and below ground. Thus, water resources must be thoroughly investigated and their development carefully managed.

This report presents a compilation of existing knowledge on the water balances of small islands and intends to prepare the basis for a future guide on hydrology and water resources management on small islands. It was prepared by the rapporteurs with the co-operation of national correspondents, United Nations agencies, non-governmental organizations, IHP Secretariat and the following IHP National Committees: Australia, Bahamas, Canada, Cape Verde, Chile, China, Colombia, Cuba, Dominican Republic, Federal Republic of Germany, Guyana, Italy, Papua New Guinea, People's Democratic Republic of Yemen, New Zealand, Norway, Portugal, Saint Lucia, Sao Tome and Principe, Spain, United Kingdom, Venezuela and Yugoslavia.

After consultation, it was agreed that IHP-III Project 4.6 should apply to islands having an area of about 1,000 sq. km , and to larger, elongated, islands where the distance between coastlines does not exceed 10 km.

3. GENERAL COMMENTS ON THE HYDROLOGY AND WATER RESOURCES PROBLEMS OF SMALL ISLANDS

As already mentioned, the availability of fresh water in small islands is dependent upon the abundance and time distribution of rainfall and also upon the storage potential above or below ground. Storage capacity depends on the presence of specific geological and topographical features, but is very limited by the impossibility to flood the small productive valleys of small islands.

The presence of perennial rivers (or large springs) is the result of exceptionally favourable quantities of precipitation and the geological and topographic conditions. Surface water is very often only available in high-rise islands.

The outflow of fresh water into the sea takes place by flowing over a penetrating aquifer wedge of saltwater, with an interposed mixing zone of brackish water of variable thickness. Under natural conditions, the nature of the aquifer rocks and their physical properties, the depth of the impermeable level, the distribution of the recharge and the fluctuations of the water table, condition the penetration of the saline wedge and the thickness of the freswater/saltwater mixture zone. If the ground is permeable in spite of the ever present saltwater that exists under the whole island, freshwater lenses may be formed which float over the seawater. This is the so-called "oceanic island" condition.

Inland springs and small streams may give rise to special ecological situations, due to the fact that the outflow of freshwater along low-lying coasts can cause marshy areas with variable salinity to develop. These areas often give the island a very characteristic appearance.

In order to build reservoirs to impound surface water, certain topographic conditions are required, which are not present in low-lying islands. Significant groundwater storage is available in islands composed of porous rock material. The least favourable storage conditions for groundwater are encountered in the coralline atolls.

Due to these limited storage possibilities, the relationship between rainfall and water resources availability is much closer in small islands than in larger islands.

In most island countries, characterized by dense population and high birth rates, the accession to independence or internal self-government has generated great hopes among the population for the improvement of living conditions. Water demand has increased significantly in all sectors of the economy following the drive of these countries towards economic self-sufficiency. Competition has developed for the limited water resources available between urban communities, rural communities, tourism (one of the major sources of income in tropical islands), small industries such as agro-industries: (sugar, oils, copra), and agriculture when irrigation is practised.

Shortage of water frequently leads to the use of urban waste water for agriculture, for which farmers previously used freshwater. Without questioning the usefulness of this waste water and its favourable effects in limiting saltwater intrusion, it is necessary to examine how it influences soils and agricultural productivity, the quality of groundwater in the short and the long-term, and the environment. The protection of springs and small rivers against pollution is a difficult, if not impossible task in the generally crowded environment of small islands, and in their fragile environment groundwater resources are particularly threatened by contaminants. Shallow wells in porous limestone, or sandy formations, are vulnerable to pollution.

By and large, water resources studies in small islands are hampered by the lack of data and a thorough knowledge of their special hydrology. This does not allow for the extrapolation of results as each island has its own particular and complex hydrological system.

It therefore appears that hydrogeological studies in small islands will be difficult if reasonably accurate and reliable results are to be achieved.

The irrational exploitation of groundwater resources may cause, according to the geological nature of the island, a deep inland penetration of the saline wedge or the expansion of the mixture zone, with a reduction in the freshwater reserves and possible salinisation of soil cover.

The selection of appropriate technologies for the development water resources in small islands and their rational use, must be the main objective of the hydrological studies.

In a small island environment, evaluating the costs and benefits of water resources development is a risky exercise which cannot be left solely to a water utility or an engineering firm to determine.

Most small islands and small island developing countries have a modest territorial extent and a major water problem. The problems go beyond the enigmas and uncertainties arising from particularly difficult hydrological conditions, such as capricious rainfall, extremely porous rocks (of volcanic origin or karstified limestone) or impervious rocks without significant storage potential, or topographical features not allowing for impoundment of surface water storage.

The water problems of recently independent small island countries result from the fact that since independence, the socio-economic context has dramatically changed in two ways: one, a desire for better living standards; and two, the need to achieve a reasonable level of self-sufficiency in an environment which tends to be overcrowded and deficient in natural resources. They arise also from the fact that the countries are isolated, with some parts of their territory (small, outer islands) difficult to reach. Accordingly, existing water policies have to be re-assessed (or non-existing water policies have to be defined) in line with development guidelines and priorities.

In particular, water resources which are scarce and/or not fully reliable have to be distributed among the various sectors of the economy and also strong environmental safeguards have to be established. This complex situation is further aggravated in small island countries by the lack of human and financial resources, both in terms of qualified personnel and adequate financing.

In some countries, the water situation has been dealt with in an efficient and economical fashion. In others, only some water development projects have been successful, but in most of these countries, goals have not been reached mainly because the technologies used were not fully adequate from the point of view of their design, the materials used, the cultural habits of the population, or because of excessive operation and maintenance costs.

The system of collecting rainwater and storing it in tanks is a very widespread one, but costly, prone to pollution and ill-suited to large concentrations of human population, peaks in demand and irrigated agriculture. Catchment by trenches or galleries is a successfull solution to the freshwater-on-saltwater situation. The exploitation of wells using mechanical pumps is increasingly widespread, but very frequently radically alters the natural conditions and leads to rapid destruction of the water reserves. The demand which then cannot be satisfied leads to the development of projects which are more compatible with the environment.

It is not unusual to see plans for, and even actual cases of, importing water by ship or producing it by desalination. The costs, however, are generally very high for the community of the island or country and have not been compared with the costs of other, more conventional solutions.

4. INTERNATIONAL ORGANIZATIONS ACTIVITIES AND PROJECTS ON SMALL ISLANDS

The IHP Secretariat asked for contributions from the Division of Ecological Sciences of Unesco, the Unesco Regional Offices for Science and Technology, as well as from specialized agencies of the United Nations System, who are involved in activities related to water resources (ECA, ECE, ECLAC, ECWA, ESCAP, FAO, UN-DTCD, UNEP, UNICEF, WHO and WMO). Contributions were also requested from the Council of Europe and the Organization of American States (OAS). The following is the information received:

4.1 United Nations System

4.1.1 United Nations Educational, Scientific and Cultural Organization (Unesco)

Unesco has promoted and supports two other projects dealing with the hydrology of small islands: a regional project in Southeast Asia and the Pacific, coordinated by ROSTSEA and a MAB project. A project dealing with the preparation of the Hydrogeological Atlas of the Caribbean Islands will be launched in October 1986 by ROSTLAC.

The Division of Water Siences, through the Regional Office of Science and Technology for Southeast Asia, and in response to the needs of Southeast Asia and Pacific countries, launched in 1985 a programme involving research studies on water resources problems of small islands (water balance of small islands project). Indonesia and the Philippines, territories consisting of more than 20,000 islands, were selected as the first countries for this programme.

In Indonesia, the study is being conducted by the Center of Environmental Studies of the Hasanuddin University in Ujung Pandang, Sulawesi. Both selected islands, Barang Caddi (34 ha) and Barang Lompo (42 ha), are flat islands of coral origin, with populations of about four and one thousand respectively.

In the Philippines, the study started on the Marinduque Island, which is representative of high islands of volcanic origin. Its area is 960 square kilometres with about 180,000 inhabitants. Another one or two islands of smaller size will be selected for the study. The research is carried out by the National Hydraulic Research Centre of the University of Philippines.

Both studies are in their early stages, and the work so far has consisted mainly of data collection. The Hasanuddin University has also started some field experiments on crop toleration to variations in the soil moisture content. The work will continue in the biennium 1986-1987. China has expressed its intention to participate in this project and to host a workshop on the topic.

The Division of Ecological Sciences carries on the project 7 "Rational Management of Island Ecosystems" within the framework of Man and Biosphere Programme (MAB). To date, the project has realized a multidisciplinary survey on a group of Mediterranean small islands: Skiathos, Skopelos, Chalki (Greece); Gozo (Malta); Kerkennah (Tunisia); Stromboli, Basiluzzo, Panarea, Vulcano, Lipari, Salina, Filicudi and Alicudi (Italy). As a result of the work the following reports were published:

Macelli, T. 1980. A Human Settlement in Gozo. Chapter 6 - Description of the water and water-use sector. Unesco/MAB and University of Malta. La Veleta.

Unesco, 1981. Iles mineures de la Mediterrannee - Salina. Serie Etablissements humains et environnment socio-culturel, No. 25. Paris.

Unesco, 1981. Iles mineures de la Mediterranee, Skiathos - Skopelos. Serie Etablissements humains et environnement socio-culturel, No. 26. Paris.

Unesco, 1981. Iles mineures de la Mediterranee. Archipel de Kerkennah. Serie Etablissements humains et environnement socio-culturel, No. 27. Paris.

Unesco, 1981. Minor Islands of the Mediterranean, Gozo, Malta. Serie Etablissements humains et environnement socio-culturel, No. 28. Paris.

Moutsopoulos, N. et al. Skiathos - Skopelos. Essai d'une etude de l'ecologie sociale des ecosystemes insulaires des Sporades septentrionales. Universite Aristotle de Thessalonique, Faculte d'Architecture, Thessalonique.

A. Aureli, C Blanco, P. Carveni, A. Cicala, V. Vigottini, S. Rizzo, C. Sturiale, G. Torre, 1984. Caratteri generali e cenni preliminari sull'ambiente abiotico dell'arcipelago eoliano, in: Atti dei convegni dei lincei No. 62, La biogeografia delle Isole. Accademia Nazionale dei Lincei, Roma.

GERSAR (Groupement d'etudes et realisations des societés d'amenagement regional), 1985. Recherches hydrogeologiques dans les iles Cyclades. Paris.

GERSAR, 1985. Recherches hydrogeologiques dans les iles du Dodecanese. Paris.

GERSAR, 1985. Notes provisoires sur l'equipement des nouveaux forages de Chalki. (roneo), Paris.

A survey of the islands of Fomentera and Gomera (Spain) is also in preparation.

Within the framework of this MAB project, a Workshop entitled "Risk Assessment of Agrochemicals in Tropical Island Ecosystems" was held from 27 October to 2 November 1984, in Saint Lucia, organized by the Caribbean Agricultural Research and Development Institute (CARDI) and Unesco.

In October 1985, researchers, planners and managers concerned with the management of the small Mediterranean islands of France, Greece, Italy, Malta, Spain,Tunisia and Yugoslavia, met in Ibiza and Fomentera (Spain) to discuss the particular problems posed in the management of small islands ecosystems.

4.1.2 United Nations Department of Technical Co-operation for Development (UN.DTCD)

The predecessors to the Water Resources Branch, Natural Resources and Energy Division of the Department of Technical Co-operation for Development have provided technical assistance in the field of water resources to almost all of the developing countries since the early 1960s. The assistance includes all aspects of conventional water resources exploration, assessment, planning, development, use, protection, conservation and legislation, from simple well digging operations to integrated river basin development. In the last twenty years or so, the Water Resources Branch was also involved in the assessment, planning and development of non-conventional water resources, such as desalination of sea or brackish water and re-use of reclaimed waste water.

The involvement of the Water Resources Branch of UN.DTCD in water problems of small islands goes back to 1961-1963 when the UN sent a hydrogeologist to Barbados to help the Government to explore, assess and develop the island's groundwater resources. Boreholes were drilled and a comprehensive survey carried out. Since then, technical assistance in the form of long-duration projects (one year or longer) has been provided to small islands throughout the Caribbean, Mediterranean, Indian Ocean and Pacific areas. The islands assisted include: Bahamas, Barbados, Bermuda, British Virgin Islands, Cape Verde Islands, Cayman Islands, Comoros, Dominica, Malta, Montserrat, Samoa, St. Christopher and Nevis, St. Lucia, St. Vincent and the Grenadines, Zanzibar (Tanzania), Turks and Caicos Islands.

Moreover, short consultancy missions (one week to one or two months) were carried out by UN Inter-regional Advisers and private consultants to the following island nations: Anguilla, Cook Islands, Crete (Greece), Netherlands Antilles, Federal States of Micronesia (Panope, Truk, and Yap Islands), Kiribati, Maldive Islands, Marshall Islands (Kwajalein-Ebeye), Mauritius, Nauru, Niue, Saipan (North Marianas), Seychelles, Solomon Islands, Tonga, Tuvalu and Vanuatu.

Taking into account the special economic development problems of many island countries, especially the difficulties of transport and communications, distance from markets, the smallness of their economies and markets, their limited natural resources etc., the United Nations General Assembly passed a resolution (No. 32/185 of 19 December 1977) on an Action Programme in Favour of Developing Island Countries.

This resolution did not differentiate between large and small island countries, even though most of the mentioned difficulties are more serious the smaller the size and the population of the island country.

DTCD's projects have dealt with a wide range of water resources activities in islands smaller than about 5,000 sq.km., according to the needs of each island country.

Assistance to islands in the Caribbean Region

In the Caribbean, under the UN.DTCD Regular Programme, inter-regional activities related to water problems in the small islands sere initiated in 1979. The project started as a preparatory assistance project for 16 months and then continued to be financed by the DTCD Regular Programme for two more years. In early 1983, UNDP Regional Funds became available for the major expenditures of the project, with minor inputs contributed by the Regular Programme.

The primary objective of the Caribbean project is to exploit economically and manage soundly all water resources in small islands of the region. By making water available for agricultural and municipal purposes, the project has helped increase employment, food production and foreign exchange. At the level of the individual countries, the objectives are: to assess the status and potential of existing water supply systems and of present and future demand; to evaluate options for alleviating water-related problems; to plan, design and execute engineering works to achieve rational exploitation and management of water resources; to promote interregional efforts and technical co-operation among developing countries of the region by pooling specialized equipment, expertise and training; to strengthen institutions; and to achieve the objectives of the International Drinking Water Supply and Sanitation Decade.

DTCD's technical assistance has provided training (fellowships and study tours) to local personnel, short advisory services and longer-term projects over several years. In these latter projects, a national team with the assistance of one or more experts and consultants has conducted through studies on the available water resources. The studies have been based on existng and sufficient newly-collected data. The projects initiated planning for exploitation of the resources and also started construction of the water works and testing of the new water systems. Bahamas, Barbados and Bermuda are good examples of such projects. On the other hand, limited short-term consultant missions may not have sufficient time or information on water resources to be able to provide best solutions to water supply problems.

In most cases the funds allocated for technical assistance are proportional to the size of the receiving country and the country's population. The allocation to small island countries is often not enough to support a full-fledged long duration water project. To overcome this limiting factor in the small island countries of the Caribbean, UN.DTCD's regional project based in Barbados has provided expert services shared by the participating countries. Work on a continuous basis has gone on the Cayman Islands, Dominica, Grenada, Montserrat, St. Lucia, St. Vincent and the Grenadines, Turks and Caicos Islands. On Antigua, the British Virgin Islands and St. Christopher and Nevis, the project has been working intermittently.

This project has several unique features. It has provided extensive assistance to individual island nations with very limited resources. The regional umbrella project based in Barbados, co-ordinates inputs, provides technical guidance, communicates with United Nations and other international and bilateral organizations and assists in preparing documentation for financing. The total expeditures of the project from 1979 to 1985 amounted to approximately $2.7 million.

In order for the project to achieve its objectives, it has been necessary to collaborate with other United Nations agencies as well as with regional institutions and aid agencies. The extent of this collaboration is considered remarkable. The general water resources projects currently being carried out in the Caribbean have generated direct investment to date of over US$3 million by the governments themselves, and have played a major role in mobilizing inputs of another $27 million form international and bilateral donor agencies for water resources development in other island countries.

The funding agencies involved are as diverse as the British Development Division, the Caribbean Development Bank (CDB), the Canadian International Development Agency (CIDA), the European Development Fund, the Netherlands Government, the Organization for Petroleum Exporting Countries (OPEC), and the United Nations Children's Fund (UNICEF).

One of the earliest collaborative efforts initiated by the project was the Seminar on Caribbean Small Islands Water Resources: Assessment, Development and Management, held in Barbados in October 1980. This was jointly sponsored by the United Nations, the Commonwealth Science Council and the Government of Barbados. A Similar seminar is planned for the Pacific region in mid-1987.

The project was evaluated by a UNDP consultant who praised the way it was conceived and designed and highly appreciated the results achieved on the different islands. The details of individual country projects are:

Cayman Islands

In 1967 the hydrogeologist in charge of a technical assistance project in Honduras visited the Cayman Islands. He investigated the groundwater potential of Grand Cayman and the two smaller islands and provided detailed technical advice with regard to groundwater development in the islands, where a scarce groundwater resources in Karshi limestone is threatened by sea water intrusion. Since than time, studies have been carried out on: groundwater assessment; new water collection, storage and treatment works; sewerage planning, storage, treatment, disposal and new works; and reformed water laws and administration. Plans have been prepared for a water quality control laboratory, a computer data bank for inventories and a 20-year Master Plan for Water and Sewerage. In August 1984, a short-term consultant was sent to advise on the best and most applicable method of producing water by desalination for Georgetown.

Dominica

The DTCD project work carried out in Dominica has included: reports on geology, water resources and water quality control; an archive data bank; plans for a chemical laboratory; designs for improvements in the water supply and distribution system; proposals for water legislation; and proposals for external funding of projects. A major initiative involved reports on marine transportation and marketing followed by designs of works to facilitate bulk shipment of water. The reservoirs, pipeline and loading facilities were later constructed with outside funding, and Dominica has now become the major water exporter in the Caribbean.

Montserrat

In Montserrat, reports on geology water resources and water quality control were produced, along with engineering inventories of existing systems and plans for improvement. A 10-year Master Plan for water resources development has incorporated proposals for groundwater development, improvements in water law, preparation of projects for external financing, new works and distribution systems.

St. Lucia

A hydrogeological survey was carried out under the DTCD-executed project and proposals were made for groundwater development and engineering works. Meteorological networks and hydrological data collection were introduced. Other activities included the drafting of national agricultural water legislation and resistivity surveys in the valleys of Northern St. Lucia.

Bahamas

DTCD-executed water projects in the Bahamas have been carried out over the period 1975-1986. The main achievements of the projects have been: to

prove the existence of large quantities of groundwater on New Providence; to formulate a plan for national abstraction of those resources; and to assist in the construction of an abstractive system. The system will provide good quality water at a cost of one-third or less than water from other sources. Other achievements include strengthening of the capability of the Water Corporation to deal with the complex issues of water resources assessment, planning, development, management, protection and conservation and water quality monitoring. Studies were also carried out on the transport of water by tanker from Andros to New Providence Island, and facilities were constructed with assistance from the World Bank to make such transport possible. Other activities under the DTCD project included the drafting of water legislation, day-to-day operation of the water barging, the establishment of a water chemistry laboratory, the rehabilitation of old government well fields and water mains, leak detection and training of technicians. Considerable follow-up investment in the water sector has been generated by this project.

St. Vincent and the Grenadines

Studies were made on the geology, water resources and water quality control on all the islands and designs were prepared for municipal water supply system improvements and water collection and storage works. A water law was drafted and a 10 to 20-year Water Resources Master Plan was initiated. Groundwater exploration and strengthening the capacity of the Water Authority to manage water resources are on-going activities.

Turks and Caicos

A study on "Development of Water Supply and Environmental Sanitation Services" was carried out in 1980 and 1981 by the Pan American Health Organization (PAHO), which included a Water Resources Master Plan. In 1983 the Government requested assistance under the DTCD-executed regional project to help implement the recommendations included in the PAHO report. DTCD's assistance has mainly been in the form of: drafting water legislation; preparing designs for pipelines to connect several reservoirs; planning and designing improvements in the water supply systems of several of the islands; investigating groundwater availability on Providenciales, including exploration drilling; and investigating the use of runways as rainwater catchments for use in agriculture and industry.

Grenada

A DTCD Associate Expert was assigned to assit in the improvement of domestic water supply. The objectives of the project are to assess total water resources, prepare an outline for a 10-year development plan, including design and cost estimated for capital investment. Reports have been prepared on existing groundwater knowledge, laboratory facilities and geophysical surveys.

Other Islands of the Caribbean

Assistance to other islands in the region has been in the form of short-term consultancies for advice on specific topics, training of technicians and short-term missions.

In the British Virgin Islands, reports have been prepared on water legislation and administration, assessment of the capability of the water laboratory and on geology, water resources, geophysics and groundwater movement and quality. These have been used as inputs to the Master Plan for Water Resources.

In Antigua and Barbuda, studies were completed on: conservation and protection of water resources; water legislation; recommendations on drought relief, including on barging water from Dominica; surveys of groundwater abstraction and quality; and required laboratory equipment.

In St. Christopher and Nevis, a review of water legislation was prepared and a one-week training workshop for water quality control was conducted. In Anguilla a five-day training mission in water quality control was made.

In the Netherlands Antilles, engineering surveys were undertaken in Saba and St. Eustacius and recommendations were made in two project reports. A Major Interregional Seminar on the Use of Non-Conventional Water Resources in Developing Countries, organized by DTCD in co-operation with the Government, was held in Curacao in April 1985.

Assistance to Islands in the Mediterranean and Africa

Simultaneously with the work being carried out in the Caribbean, DTCD had active projects on islands in other parts of the world. The earliest project was a groundwater and mineral resources survey carried out in Cyprus from 1963-1969. An overall assessment of groundwater resources was made and hydrogeological maps were prepared. Over 170 boreholes were drilled and considerable monitoring and testing were carried out.

In Malta, DTCD's project was primarily concerned with development and conservation of water resources. Schemes to improve storage facilities and surface water quality were developed from 1979-1982.

In Cape Verde, a groundwater exploration project was carried out from 1975-1979. This involved assessment of water resources potential, drilling of wells and formulation of guidelines for national water policy. On one of the islands, a large desalination project was initiated, which later led to considerable external investment.

A more recent project has been initiated in the Comoros Islands for water resources investigation and development (1980-1986). Under this project, wells for urban and rural community water supply have been drilled.

Assistance to Islands in the Pacific Region

During the 1970s, projects involving hydrogeological surveys and data collection were also carried out in Fiji (1971-1973) and Samoa (1974-1978) in the Pacific region. It became clear that many of the islands of the Pacific faced problems in water resources development similar to or even more acute than those in the Caribbean and other parts of the world.

It was therefore proposed, as part of DTCD's global effort, to extend the objectives of earlier projects to the Pacific region. Such a recommendation was made at the Workshop on Small Islands, held in Suva from 2 to 9 July 1984.

Based on the experience gained in the Caribbean, DTCD has initiated a similar regional project for the island countries of the South Pacific. During the preparatory phase, the needs for long-term assistance in the field of water resources for each small island requesting it will be assessed, project documents will be prepared, co-ordination with other aid programmes will be established, and funds for carrying out a large-scale regional water project will be sought.

It is expected that the project would lead to large-scale investment in water resources development from international, bilateral and multilateral funding organizations. Improving water supply for human consumption, small-scale irrigation, industry and tourism provides a basis for economic and social development.

Water is one of the major natural resources of the islands, which are poor in productive soils, minerals and energy. Water demand has been rising rapidly as a result of: concentrations of population in a small number of crowded areas; the presence of military installations; the development of luxury hotels; and rising living standards of the population.

A number of steps have been proposed to improve the situation of water resources in the Pacific region, however, some of which have been incorporated into the objectives of DTCD's interregional projects. A programme of action was initiated by the ESCAP Secretariat and was adopted at the conclusion of the ESCAP meeting on Water Resources Development in the South Pacific (Suva, March 1983).

The recommended programme dealt with various aspects for which actions (projects, investigations, training sessions, studies, drafting of legislation) were proposed, which may require the involvement of the United Nations System or some form of external assistance, especially for the following:

- water resources assessment and management, particularly in atolls;
- improvement of water supply systems;
- protection against sea water intrusion;
- determination of appropriate technologies for water collection;
- water pollution control;
- development of a water policy;
- training of water specialists;
- disaster mitigation

4.1.3 World Meteorological Organization (WMO)

The special conditions governing operational hydrology activities on small islands have long been of interest to WMO and its various constituent bodies, but up until now the relevant experience and recommendations have not been compiled into a single report or a set of reports. Nevertheless, some 20 years ago recognition was given to these special conditions of when recommended densities for hydrological networks were published in the Guide to Hydrological Practices, giving different densities for small islands.

WMO Regional Association V (South-West Pacific) has a particular interest in this question because it consists of several countries that are composed mainly of small islands. The hydrological problems and needs of these islands often require special attention and different approaches, especially in connection with the development of water resources for various uses. Their insularity, their geological and physiographic features, and often their isolation from large land masses, tend to produce hydrological regimes which vary greatly from those experienced in larger land masses, and, in fact, can vary from island to island in the same general location. Their water resources are not only small by nature, but also occur in an extremely fragile environment and hence are very susceptible to salt-water intrusion and pollution.

Therefore, priority should be given to water-resources assessment guidelines applicable to the world's small islands, noting the special nature of hydrological aspects of their water-resource development. WMO considers l

that the term "small islands" includes those islands which are less than 1000 sq.km. in area, and also bigger isolated islands which could be as much as 200 000 sq.km. but experience hydrological regimes similar to those of small islands. In the report of the first session of the Association's Working Group on Hydrology (Manila, 26-30 November 1984) some reference is made to small islands.

WMO have also co-operated with ESCAP in the same region in field missions to the island countries. The relevant reports are:

WMO/ESCAP Tropical Cyclone Survey. Mission to the South-West Pacific 27 October 1983 to 7 December 1983 (Australia, Cook Islands, Fiji, New Caledonia, New Zealand, Papua New Guinea, Solomon Islands, Tonga, Vamatu, Western Somoa).

Hall, A.V. Overseas Mission, July 1984 (Java, Vamatu, Turaly and Tonga).

The Caribbean is the other major area of interest where WMO has become very much involved in recent years in encouraging the development of national activities and regional co-operation in operational hydrology. A WMO-executed regional project, the Caribbean Operational Hydrology Institute (COHI), got underway in September 1982. This Institute is located in Barbados and has recently been amalgamated with the long-established Caribbean Meteorological Institute. The booklet "The Caribbean Institute for Meteorology and Hydrology" provides some background information. The objectives of the project are to train two levels of hydrological technicians and to assist the 14 English-speaking member of the Caribbean Meteorological Organization to establish or improve their networks of hydrological stations. Current plans include the establishment of a centralized data bank and data processing facilities at the Institute.

4.1.4 United Nations Economic and Social Commission for Western Asia (ECWA)

The Natural Resources Science and Technology Division of the Economic Commission for Western Asia has prepared two publications related to the subject, namely E/ECWA/NR/Conf.1/8 entitled "Country Report, the State of Bahrain" and E/ECWA/NR/L/1/Rev.1 entitled "Assessment of the Water Resources Situation in ECWA Region", giving on pages 47-56 information about Bahrain, which is the only island state is the ECWA region

Other important islands in the ECWA region are: Arwad (Syria), Socatra (Democratic Yemen), Maseira (Oman) and Waraba and Bubiyan (Kuwait), for which no detailed information is available at present.

4.2 Other Organizations

4.2.1 Council of Europe

During their meeting in Paris on September 17, 1984, the European Ministers for Research decided the setting up of 25 European Networks of Scientific and Technical Co-operation, one of them devoted to the management of water resources and including a topic on water management on medium-sized and small islands and along coastal areas.

The Council of Europe considers that medium-sized islands may provisionally be defined as those having an area of between 10,000 and 2,000 sq.km. and small islands as those having an area of between 2,000 and 200 sq.km. Islands not exceeding 200 sq.km. may be described as very small

islands. Other classifications are possible by reference to the relief, shape, climatic and hydrometeorological conditions, rock permeability and nature of the soil.

In addition to the proposals adopted at the European Workshop on Hydrologic Management in Mediterranean Islands held at Nicosia, from 15 to 17 October 1984, objectives have been defined and it is also proposed to focus the Council of Europe network's activities on small islands of the Mediterranean regions.

The similarity of the climate, the environment and the relative importance of the seasonal variation in population, seasonal character of the rainfall, peaks in demand, etc., have given rise to similar hydrological problems for the majority of Mediterranean islands and to possible solutions and experiments which could be immensely facilitated by a co-ordinated and co-operative regional programme for the study and management of water resources.

The aim of the Council of Europe's network is to promote the establishment of a real scientific and technical European area, ensuring a better co-ordination of research. The networks should be designed in such a way as to enable the building up of international and interdisciplinary research programmes and in the case of the network devoted to the management of water resources, to devise management methods which could be extrapolated and become general. With this aim in mind, the Council considers it is necessary to promote:

- the bringing together of ideas, human resources and equipment, training capacities and expertise;

- the spreading of scientific information, by organizing workshops, symposia);

- the exchange of research workers including post-graduate students, by providing research grants for complementary training or specialization.

A network should be self-managed, in that its organization and scientific supervision are a matter for the scientists themselves. The scientific community should seek for appropriate support structures and the financial means from national, community or international sources.

A meeting was held in Lyon from 3 to 4 March 1986. The main aim of this first meeting was to allow the representatives of the European laboratories concerned to discuss the proposals of these topics and to proceed further in the organization of the European network on the management of water resources. The participants at the meeting considered that the setting up of the European network of scientific and technical co-operation in the field of management of water resources would be a concerted contribution of European research workers to international research programmes such as the International Hydrological Programme (IHP) of Unesco.

In summary, the meeting concluded :

a) Co-operation priorities among the European Organizations

Improvement of Water Resources technology

- water balance of islands and small coastal basins
- recovery of freshwater lost to the sea, both on the surface (permanent or stormy) and underground

- sea water intrusion as a consequence of freshwater exploitation
- artificial recharge as a means to reduce freshwater outflow

Water protection and conservation aspects

- water re-use for irrigation and even other uses - nitrate pollution, salinity increase, health problems, public concern and agricultural production related problems when implementing water re-use schemes - water desalination.

Economic, social and environmental aspects

- comparing water use alternatives - environment preservation and environmental impact - monitoring including remote sensing methods - evaluation of economic and social impacts - water demand forecasting for tourism and other users

b) Basic information

A detailed survey on islands and coastal areas is needed, followed by the implementation of a data bank available to all interested organizations and laboratories.

c) Training

Training programmes will be proposed by the scientists of the network and in co-operation with other existing training centers,

The following institutions have indicated their readiness to co-operate in the network on Water Management on Medium-sized and Small Islands and Elongated Coastal Areas:

University of Malta (Malta)
Water Development Department (Cyprus)
Institute of Earth Sciences of Catania (Italy)
Polytechnic University of Valencia (Spain)
Polytechnic University of Barcelona (Spain)
Technical University of Lisbon (Portugal)
National Laboratory of Industrial Engineering and Technology (Portugal)
Municipal Corporation for Water and Sewerage -Palma de Mallorca (Spain)
General Directorate for Water Resources Las Palmas. The Canaries (Spain)
Geological Institute of Gent (Belgium)
University of Cagliari (Italy)
Grandi Masse Laboratory of Venice (Italy)
Institute of Applied Geology of Bari (Italy)
University of Torino (Italy)
IRSA , Roma (Italy).

4.2.2 Organization of American States (OAS)

The Department of Regional Development of OAS has carried out water balance computations in the following Caribbean islands since 1981: Saint Lucia, Antigua, Barbuda, St. Vincent and Carriacou (Grenada).

St. Lucia:

In order to construct an adequate framework for the planning of activities of the Ministry of Agriculture, the OAS has evaluated both the basic information on the island's water resources as well as, at the national

level the balance of these resources; formulated recommendations for management and development policies of water resources based on the priorities of counterpart agencies, and identified project outlines and immediate priority actions.

The water balance computations were based on a rainfall gauge network covering one third of the identified 30 river basins of the island, four climatological stations, and discharge measurements from seven streams.

Antigua and Barbuda

A report was prepared as part of a Natural Resources Assessment for the Agricultural Development Project in Antigua and Barbuda. Emphasis is focused on surface water storage for supplemental irrigation, as small ponds and surface catchments have been an important source of agricultural water supply for many years.

The report contains a review of the water balances and rainfall data for both islands; a study of the data collection process for rainfall data and suggestions for improvements; estimate of the potential supply of water for agriculture on a watershed (or regional) basis, including a review of existing data on present and potential capacity of catchments and the demands for non-agricultural water; appraisal of the unit cost of agricultural water from the various sources considering the cyclical drought conditions which occur in Antigua and Barbuda, and a map of the present and potential sources of agricultural and non-agricultural water on a watershed basis wth an indication of capacities of each source, including groundwater.

St. Vincent

A report assessed the availability of water for municipal, irrigation and hydropower uses for the northeastern part of St. Vincent. Recommendations were provided to guide both development and protection of the area's water resources in a manner which will suport desirable patterns of economic development and minimize use conflicts.

The report contains an analysis of watersheds from the Cayatul to the Ayacoa River; recommendations concerning the legal and administrative policies for the management of these resources and programmes for the development, protection and utilization of water; an assessment of present and future pollution problems and other aspects which may affect the future supply of good quality water in sufficient quantity for the uses noted above.

Carriacou (Grenada)

The report contains an assessment of the existing situation of water resources and related infrastructure and proposals concerning its development. It analyses yields of the groundwater well network and storage capacities of perennial ponds. Water resources estimates were made for a three-month dry period preceding a wet season.

5. RELEVANT INTERNATIONAL SCIENTIFIC EVENTS ON THE HYDROLOGY OF SMALL ISLANDS

Since the mid-1960's the theme has become a subject of international interest. Events of various nature have been organized for the identification of the problems and the exchange of experience.

The most recent and specific events on the hydrology of small islands are:

Seminar on Hydrology of Volcanic Islands and Terrains, organized by Unesco and the General Directorate of Public Works of Spain and under the auspices of the UNDP and the Spanish Government. Arrecife de Lanzarote, Canary Islands, 1974.

Seminar on Selected Water Problems in Islands and Coastal Areas, organized by the United Nations Economic Commission for Europe. San Anton, Malta, June 1978.

Seminar on Small Islands Water Problems, organized by the United Nations and the Commonwealth Science Council, Bridgetown, Barbados, October 1980.

Workshop on Water Resources of Small Islands, supported by the Commonwealth Science Council, the United Nations and Unesco. Suva, Fiji, July 1984.

European Workshop on Water Resources Management of Mediterranean Islands, organized by the Council of Europe. Nicosia, Chypre, October 1984.

International Seminar on Development and Management of Water Resources in Small Islands, sponsored by the United Nations and the Government of Bermuda, Hamilton, Bermuda, December 1985.

Seminar on the Management of Water on Mediterranean Small Islands and Isolated Coastal Zones, organized by UNEP, WHO, Gobierno de la Comunidad Autonoma de las Islas Baleares, Palma de Mallorca, September 1986.

Moreover, among those international events that have included topics related to the theme of hydrology and water balance of small islands, reference can be made to the following:

Fourth International Conference of the European Mediterranean Commission for Water Planning. Marseille, France, May 1982.

Meeting on Water Resources Development in the South Pacific, organized by ESCAP. Suva, Fiji, March 1983.

International Conference on Groundwater and Man, organized by the Department of Resources and Energy. Sidney, Australia, December 1983.

International Seminar on Non-Conventional Water Use in Developing Countries, sponsored by the United Nations. Willemstad, Curacao, Netherlands Antilles, April 1984.

Fifth International Symposium on Groundwater, organized by the European Mediterranean Commission for Water Planning and the International Association of Hydrogeologists. Taormina, Sicily, November 1985.

6. INFORMATION AVAILABLE ON THE WATER RESOURCES OF SMALL ISLANDS

Specific technical literature dealing with water balance and water resources management of small islands is scarce in spite of the great number of papers and reports prepared on the matter by international organizations, governments and specialists. The following list includes the related documents made available to the IHP Secretariat to date as contributions to IHP-III Project 4.6.

It should be considered as a preliminary list, but at the same time it should be pointed out that together these documents include thousands of references on basic data, hydrology, hydrogeology, climate and hydraulic works on small islands. In order to facilitate the information retrieval, documents are classified into five main topics, these are:

6.1 General reports

Chapman, T.G., 1985. The Use of Water Balances for Water Resources Estimation with Special Reference to Small Islands. Pacifical Region Team. Australian Development Assistance Bureau. Bulletin No. 4. Sydney.

Custodio, E., 1978. Geohidrologia de Terrenos e Islas Volcanicas. Centro de Estudios Hidrograficos e Instituto de Hidrologia. Publ. 128. Madrid.

Dijon, R., 1983. Some Aspects of Water Resources Planning and Management in Smaller Islands. Natural Resources Forum. Vol. 7, No. 2. United Nations, New York. p. 137-144.

6.2 Regional bibliographies

Beavington, C.F. and Williams, J.B., 1980. Bibliography of Water Resources of Commonwealth Countries in the Caribbean and the Mediterannean. Commonwealth Committee on Mineral Resources and Geology. Special Liaison Report. CGLO SLRS London.

Dale, W.R. 1984. A Bibliography of Hydrology of Small Islands. A list of some recent publications with particular reference to coral reef islands of the Pacific. Wellington.

Hadwen, P., 1980. Caribbean Small Islands, Water Resources Assessment Development Management. A first bibliography of geology, hydrogeology and water resources. United Nations. CAR/79/ROI. Bridgetown.

Thompson, B.N., 1984. Geological Maps of the Islands of the South Pacific. New Zealand Department of Scientific and Industrial Research. South Pacific. Technical Inventory No. 4. Wellington.

6.3 Regional reports

Goodwin, R.S., 1984. Water Resources Development in Small Islands. Perspectives and Needs. Natural Resources Forum. Vol. 8, No. 1. United Nations. New York. P. 63-68.

United Nations Department of Economic and Social Affairs, 1976. Ground Water in the Western Hemisphere. Natural Resources/Water Series No. 4. New York.

United Nations. Department of Technical Co-operation for Development, 1983. Ground Water in the Pacific Region. Natural Resources/Water Series No. 12. New York.

6.4 Proceedings of international events

Proceedings of the International Conference on Water for Peace. Washington, D.C., United States of America. 1967.

Proceedings of the Seminar on Selected Water Problems in Islands and Coastal Areas with Special Regard to Desalination and Groundwater. San Anton, Malta, 5-10 June 1978, published by Pergamon Press., 1979. New York.

Proceedings of the Conference on Environmental Management and Economic Growth in the Smaller Caribbean Islands. Wildey, Barbados, 17-21 September 1979. Department of State. Publication No. 8996. International Organization and Conference Series 143. Washington, D.C.

Proceedings of the Seminar on Water Resources Assessment, Development and Management in Small Oceanic Islands of the Caribbean and West Atlantic. Bridgetown, Barbados, 6-10 October, 1980. United Nations and Commonwealth Science Council.

Proceedings of the Fourth International Conference on Water Planning of the Mediterranean European Commission. Marseille, France, 10-12 May 1982. Bulletin du BRGM. Deuxieme Serie. Section III. No. 314. Orleans.

Proceedings of the International Conference on Rain Water Cistern Systems. Water Resources Research Center, University of Hawaii, Manoa. June 1982.

Proceedings of the Meeting on Water Resources Development in the South Pacific. Suva, Fiji, 14-19 March 1983. Economic and Social Commission for Asia and the Pacific. Water Resources Series No. 57. United Nations, New York.

Proceedings of the International Conference on Groundwater and Man. Sydney, Australia, 1983.

Proceedings of the Workshop on Water Resources Management of the Mediterranean Islands. Nicosia, Cyprus, 15-17 October, 1984.

Proceedings of the Regional Workshop on Water Resources of Small Islands. Suva, Fiji, 27 June - 9 July 1984. Commonwealth Science Council. 1985. Technical Publication No. 154. London.

6.5 Specific reports

6.5.1 Atlantic ocean, small islands

Babau, M. et al. 1981. Les conditions generales au Cap Vert. Ministere du developement rural. Praia.

Beltrao, A.E., 1974. Aspectos Hidrogeologicos do Territorio Federal de Fernando de Nororonha. SUDENE. Serie Hidrogeologia No. 49. Recife.

Bourguet, L., 1981. Esquisse de schema directeur du developpement rural de l'archipel du Cap Vert, Burgeap - Ministere du developpement rural. Praia.

Burgeap, 1974. La mise en valeur des eaux souterraines dans l'archipel du Cap Vert. Paris.

Cunha, F.R., 1961. O Balanco hidrologico na ilha de Santiago - Cabo Verde. Estudos Agronomicos. Lisboa.

Custodio, E., Saniz Oiza, J. 1972. Estudio hidrogeologico de Lanzarote. Servicio Geologico de Obras Publicas. Las Palmas de Gran Canaria.

Custodio, E., 1973. Estudio Hidrologico de Lanzarote. Servicio Geologico de Obras Publicas, Las Palmas de Gran Canaria.

Gonfiantini, R.; Gallo, G.; Payne, B.R.; Taylot, C.B.; 1976. Environmental isotopes and hydrochemistry in groundwater of Gran Canaria. Interpretation of Environmental Isotope and Hydrochemical Data in Groundwater Hydrology. Vien

Laboratorio Nacional de Engenharia Civil, 1981. Estudo Global dos Recursos Hidricos da Ilha de Porto Santo. Lisboa.

Lopez Garcia, L.; Amigo, E.; Custodio, E; 1981. Planteamiento y ajuste de un modelo matematico de simulacion de la isla de Tenerife. Proc. IV. Nat. Assem. Geodesy and Geophysics. Madrid, Vol. III. P. 1643-1673.

Loureiro, J.J.M., 1980. Monografia Hidrologica da Ilha das Flores, Acores. Direcao Geral dos Recursos e Aproveitamentos Hidraulicos. Lisboa.

Loureiro, J.J.M., 1984. Monografia Hidrologica da Ilha da Madeira. Recursos Hidricos. Revista da Associacao Portuguesa de Recursos Hidricos. Vol 5, No.2. Lisboa, p. 53-73.

Neira, H.C., 1985. Bilan hydrique de deux bassins versants de l'ile de Santiago pour 1984 et 1985. Praia.

PNUD, 1983. Modelisation hydrologique de bassins versants menant a l'etude du ruissellement, de surface et de l'ecoulement souterrain. Republique du Cap Vert.

6.5.2 Caribbean small islands

Diaz Arenas, A.; Valdes Gonzalez, A., 1985. Sobre la Necesidad de Nuevos Enfoques en los Estudios Hidrologicos y Explotacion de los Recursos Hidricos de Pequenas Islas sin Posibilidad de Almacenamiento Superficial. Instituto de Hidroeconomia. La Habana.

Febrillet, J.F; Perez Perez, O.; 1985. Recursos Hidraulicos de las Islas Saona y Beata. Instituto Nacional de Recursos Hidraulicos. Santo Domingo.

HIMAT, 1983. Disponibilidad de Agua Dulce Superficial. Arroyo Agua-Dulce. Isla Providencia. Bogota.

HIMAT, 1982. Estudio de Escorrentia Superficial de la Isla de San Andres. Bogota.

IMPOISLAS, 1970. Estudio de Aguas Subterraneas en la Isle de San Andres.

Servicio Colombiano de Meteorologia e Hidrologia (hoy HIMAT), 1971. Estudio para el Aprovechamiento de Agua Potable. Aperiodica No. 21, Bogota.

6.5.3 Indian ocean small islands

Burgeas, A., 1984. Evaluation globale de la ressource en eau de l'ile de La Reunion. Apports de la simulation par modeles hydrologiques. BRGM. Service geologique national. Departement eau. 84SGN232 EAU/REV. Orleans.

Government of Maldives, 1985. National Programme for Water Supply and Sanitation

Kenchington, R.A., 1985. Report on Mission to the Republic of Maldives during October 1984-February 1985. Great Barrier Reef Marine Park Authority, Townsville.

Raghava Rao, K.V., Mendis, D.P.J. and Asoka Perera, H.A.S., 1984. Groundwater Investigation for Community Water Supply Source in Marinar Island. National Water Supply and Drainage Board and World Health Organization. Ratmalana.

6.5.4 Pacific ocean small islands

Falkland, A., 1982. Norfolk Island Hydrology. Progress Report. Department of Transport and Construction.

Falkland, A., 1983. Christmas Island (Kritimati) Water Resources Study - Republic of Kiribati. Australian Development Assistance Bureau. November

7. RECOMMENDED TABLE OF CONTENTS FOR A GUIDE ON HYDROLOGY AND WATER RESOURCES OF SMALL ISLANDS

Taking into account the current importance of a new suitable approach for the water resources evaluation and rational management in small islands, and the interest expressed by several IHP National Committees, the Rapporteurs recommend the IHP Intergovernmental Council to continue the work on IHP-III Project 4.6 by establishing a working group to prepare a Guide on Hydrology and Water Resources Development of Small Islands, whose draft table of contents is presented on the following page .

GUIDE ON HYDROLOGY AND WATER RESOURCES DEVELOPMENT OF SMALL ISLANDS

(Preliminary Draft Table of Contents)

3.6 Other sources
- conventional desalination (evaporation, reverse osmosis)
- non-conventional desalination (cheaper and simpler membranes for reverse osmosis units; solars stills)
- importation (regular, during droughts)
- weather modification
- dew catchment
- water re-use

4. WATER RESOURCES ASSESSMENT

4.1 Hydrometeorological assessment
- rainfall network. Possible re-evaluation of WMO guidelines for minimum density of equipment
- evaporation and other parameters measurement
- data analysis methods

4.2 Analysis methods for rainwater catchments

4.3 Asssessment of surface water resources
- station network, appropriate types of stations (continuous and non-continuous, strip chart and solid state data logging), gauging methods (volumetric, current meter, dilution, etc.), processing storage and retrieval of data, analyses of data.

4.4 Assessment of groundwater resources
- surface observations, drilling and testing methods, geophysical surveys
- parameter evaluation such as permeability, hydraulic conductivity, infiltration, transmissivity, porosity, specific yield
- recharge estimation using meteorological and other data
- modelling of groundwater bodies

Appropriate field equipment and techniques for above, especially in very small island context where availability of local materials and expertise is relatively low and transport and communications are often very poor.

4.5 Training aspects for water resources assessment

4.6 Further research requirements

5. WATER RESOURCES DEVELOPMENT AND MANAGEMENT

5.1 Estimation, validation of demand for water (domestic and commercial, industrial, agricultural, and stock raising if relevant, ecological)
- possible re-evaluation of WHO guidelines for minimum demand in the context of small and very small islands.

5.2 Evaluation of existing water supply systems
- detailed review of methods of collection, storage, distribution of water. In particular, materials of construction, methods of pumping and types of distribution (house connections, communal tanks, standpipes) to be considered
- conventional and non-conventional damming and surface storage methods
- conventional drilling methods: wells and water trenches or galleries
- new drilling methods: wells and water trenches or galleries
- possibilities and practice of artificial groundwater recharge

5.3 Evaluation of ecological impact of fresh water use
- springs and small rivers and their allocated environments
- swamps and coastal humid areas
- soil changes and agricultural production

5.4 Criteria for design for new systems
- simplicity
- low maintenance requirements
- use of local materials where possible
- corrosion resistant materials for pumps, tanks, pipes, fittings, etc.
- spare parts availability
- renewable energy sources where possible
- freight costs to be considered in total costings (as these costs are often much greater than purchase price of the materials and equipment)

5.5 Considerations on water quality problems (related also to the assessment phase)
- sea water intrusion problem (pump rates and trenches or galleries dimensions and efficiency)
- turbidity problem in case of some surface water systems (especially in case of high flows)
- laboratory organization, personnel and equipment
- appropriate methods for chemical and bacteriological treatment processes
- sewerage effluents. Influence of sewerage effluent zone
- municipal, agricultural and industrial pollution
- measures to protect water resources: structural (e.g. appropriate pump rates, gallery designs, river-off tape systems, roofing materials, etc.) and non-structural (e.g. land zoning, education campaigns, training)
- impact of water re-use

5.6 Considerations on soil erosion caused by high intensity rains

5.7 Possible use of other water sources in short or long term (e.g. desalination which is generally not appropriate but maybe useful in context of solar stills, fresh water, importation during droughts)

5.8 Selection of most appropriate water supply system and residual treatment which is dependent on:
- technical feasibility
- economics
- social acceptability

5.9 Important requirements of monitoring networks (this is particularly necessary for the relatively fragile freshwater less situations)

5.10 Interrelationship of sanitation of water supply systems. (Flushing water may be an extra demand on fresh water resources. Where other sources (e.g. seawater) are used then particular care to prevent contamination of fresh water resources must be taken)

5.11 Water development for other purposes than water supply (irrigation, industry, etc.)

5.12 Training aspects for water resources development and management

5.13 Public awareness and health aspects

5.14 Water resources protection against pollution and exhaustion

ANNEX

Case studies of water balance, water resources assessment and water resources exploitation in small islands.