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THE ROLE AND OPERATION OF NATIONAL HYDROLOGICAL SERVICES

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1. INTRODUCTION

1.1 Thirteenth Congress requested, by Resolution 7.2/1 (Cg-XIII), that Executive Council review the role and operation of hydrological services, and identify ways and means to ensure their further strengthening. A statement on *The National Meteorological Service and alternative service delivery* was delivered to Congress by the Executive Council, and the present paper has been prepared in order to provide an equivalent statement in respect of National Hydrological Services.

1.2 The EC statement referred to above was written in reaction to the rapidly changing organizational environment in which National Meteorological Services (NMSs) operate. Hydrological services operate in essentially the same environment, characterised in particular by a world-wide tendency for governments to seek more effective and efficient ways of delivering essential services to their national communities, during a period of financial constraint. In some respects, however, the issues that face hydrological services are different, because NMSs and water resource management agencies have evolved in quite different ways. Many countries do not have a single National Hydrological Service, equivalent to the NMS found in most countries. For this reason, the standard WMO terminology of "National Hydrological Service" and "NHS" are not used in this draft. The term "hydrological service" used herein should not be taken to imply a single service, but may include, for example, provision of water-related information by a number of provincial agencies under the oversight of a co-ordination mechanism such as a small federal commission. Nevertheless, it is worth re-affirming at this point the definition of WMO as the international body which is composed of and represents the National Meteorological and Hydrological Services of its Members, however they are structured at the national level.

1.3 The key issues facing the global community of hydrological services include:

- Growing pressure on water resources in many countries, with resultant competition for water among the different sectors of the economy;
- Increasing recognition of the need to sustain freshwater ecosystems while meeting the demands of human users;
- Increasing adoption of Integrated Water Resources Management[1] as the framework for water management;
- Growing demand for a wider range of water-related information services, such as low flow forecasting;
- The adoption of new management models developed in other parts of the economy, and the development of models that are specific to water management – especially those based on the river basin as the basic unit of management;

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[1] Integrated Water Resources Management is an approach that attempts to consider, at the same time, the many dimensions of water management practice. It is usually considered at several levels:

- The different components of the hydrological cycle – groundwater, surface water, quantity and quality etc.
- the many socio-economic demands placed on water – irrigation, hydropower, etc.
- the several components of the aquatic/catchment system – vegetation cover, soils and erosion, land use, water quality, instream ecosystems, etc
- the institutions and laws/policies in place for resource management – civil, environmental, agricultural, infrastructure agencies, etc
- the geographical entities involved – in particular, the catchment as the "fundamental unit" of management, and its relationship to the boundaries of civil and other administrations.

Hence, it is considered to include not just water, but the land, soil, rock, chemicals (of natural and human origin), dependent biota, and human institutions and activities associated with water and its use and management. Water is regarded as the "unifying element", because it is the transporting medium for particulate and dissolved matter and an essential requirement for all life, aquatic and terrestrial. Annex 1 provides a fuller discussion.

- Technological advances in data and information management, which provide greatly enhanced service opportunities but at greatly increased capital cost;
- The tendency for national/provincial governments to reduce expenditure and taxation, and to withdraw from functional areas in which they have no comparative advantage, relative to the private sector;
- Widespread acceptance of the four Principles[2] of the International Conference on Water and the Environment (Dublin, 1992), and rapidly evolving thinking on water-related issues in such fora as the UN Conference on Environment and Development (Rio de Janeiro, 1992), the UN Commission for Sustainable Development, and the international development banks.

1.4 Perhaps the most fundamental issue, however, is:

- Tendencies to redefine the role of the State in providing or funding water-related services like piped water supply, and the extent to which they could be provided more efficiently or effectively by the private sector or the services' users and beneficiaries themselves. Almost inevitably, the question will be raised as to what the role of the State should be in supplying the information required to design and operate such services.

1.5 The pace of change seems to be increasing, so that any discussion of the role and status of hydrological services should attempt to consider not just present circumstances, but those that might exist in the foreseeable future. For instance, the forecasting capabilities of National Meteorological Services are evolving rapidly, through application of improved information technology, computing power, and knowledge of the atmospheric system. Hydrological services can anticipate having within the next few years much enhanced flood and low flow forecasting capabilities, based on improved meteorological forecasts.

2. PURPOSE

2.1 This document is intended primarily to inform the directors and senior staff of hydrological services and other bodies that are responsible for national policies on, or co-ordination of, water resources management. It is a response to the environment of change in which many organisations within the WMO "family" find themselves, in which, for example, the degree of financial support from government sources declines, costs are required to be recovered from users, information is increasingly regarded as a product to be sold rather than exchanged, and governments initiate large-scale programmes of institutional restructuring.

2.2 It attempts to draw on international experience – and international visions of the future – particularly with regard to the various models of service delivery that might be applicable. While hydrological services in many countries need limited operational contact with those in other countries, the progressive development of "the global village" is presenting many opportunities to benefit from greater international interaction. This is particularly the case for groups of countries that share a major international river basin; indeed, international co-operation in river basins such as the Rhine and Danube has long been seen as essential, in everyone's interests.

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[2] The Four Principles are:

1. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
3. Women play a central part in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognised as an economic good.

2.3 It is, of course, for the officials and other stakeholders in each country to develop national policies and approaches in hydrology and water resources management, in the context of national development goals, socio-economic circumstances, and decision-making structures. However, there may be benefit in having information about how other services in other countries have responded to the changing environment. In general, there is little correspondence between the arrangements for hydrology and water resources management that are adopted, and the governmental system or stage of economic development in a particular country. Annex 1 presents information on the legal and institutional background to hydrology and water resources management in ten countries that have been selected to show a range of circumstances. They are not claimed to be “typical” or “representative”, but they demonstrate the diverse arrangements that have been adopted in different parts of the world. Basic arrangements for hydrological services in each country are listed in Table 1.

3. NATIONAL RESPONSIBILITIES IN WATER RESOURCES MANAGEMENT

The social and economic significance of water resources

3.1 As the *Dublin Statement* of the International Conference on Water and the Environment recognized, water is essential to all life, and is a basic element in many sectors of human society. It is a fundamental role of governments to ensure that their citizens receive the benefits of a well-managed water resource, such as a healthful drinking water supply, or enhanced food security from irrigated croplands. On the other hand, it is also a responsibility to protect citizens as far as practicable from the negative aspects of water, in particular floods, hydrological droughts, and water-related disease.

3.2 The socio-economic sectors that are particularly dependent on effective water resources management include:

- Agriculture: both rain-fed and irrigated food crops and crops which provide the basis of manufacturing industry, such as cotton;
- Domestic drinking water supply: clean water is a fundamental requirement for human health, and indeed for the health of domestic animals;
- Manufacturing industry: water is needed as a raw material in some industries (e.g. brewing), as a process material in others (e.g. steel production), and as a medium for waste removal in others (e.g. food production);
- Energy production: water is indispensable – obviously – for hydro-electricity generation, and as a coolant in thermal electricity generating stations;
- Navigation: many countries benefit from cheap transport of goods, often in bulk, along rivers with natural flows, and along constructed canals whose water body is drawn from rivers;
- Sanitation: water is the medium for disposal of waste in many countries (even though this is increasingly seen as an undesirable practice, because it may prevent use of the water resource for other purposes which require uncontaminated water);
- Civil defence: the provision of public warnings of floods, low flows, and pollution events is a basic role of governments, to preserve life and property,
- Fish production: hundreds of millions of people are dependent on fish for their protein intake, and fish rearing in artificial ponds, harvesting of natural fish populations in freshwater and freshwater bodies, and spawning and rearing of migratory species in estuaries and coastal areas are a few aspects of fish production that are dependent on a well-managed water resource;
- Recreation and environmental amenity: such activities as swimming and rafting, and the increasingly important economic contribution of ecotourism;

- Ecosystem maintenance: the notion of sustainable development implies that natural ecosystems, including those dependent on freshwater/estuarine water bodies, are maintained as the "bottom line" requirement.

Public and private good attributes of water

3.3 Perhaps the key issue in the water sector is to define optimal arrangements for managing water resources, in order to meet the needs of other sectors of the economy. Increasingly, a distinction is made between the functions of policy development, regulation, provision of information, management of common property resources such as water, and delivery of (potentially) commercial services such as piped water supply. Government agencies do not need to be involved in all of these types of function, and they probably should not be, to avoid conflicts of interest. Government agencies may have no comparative advantage, and a particular function may be more efficiently discharged by the private sector or a non-governmental public organization.

3.4 A government most obviously has a role in providing services or goods with public or social good attributes. These cannot (or must not) be appropriated by anyone to the exclusion of others; they are not "used up"; or they benefit common property resources, the environment or the community at large (including future generations). Policy development, regulation, and related legal functions are obvious areas in which governments have a role, to avoid any part of the community establishing a level of control that disadvantages others. So too is management of the environment and common property resources, since history has shown clearly that there is a strong incentive for individuals to exploit them until they are unusable or lost. Services that are delivered to defined customers/beneficiaries are not public goods, and may well be more efficiently delivered by the private sector. However, the capital investment required (for example, to construct an irrigation scheme) may be too great for the private sector or the beneficiaries to assemble, or the projected return may be insufficient or too far in the future to justify the investment.

3.5 Water-related information has attributes of both public and private goods. Some information, such as a flood warning, may benefit the community as a whole and be non-appropriable once it is disseminated. Other information, particularly when it has been tailored to meet the specific needs of a particular user and is transmitted via secure communication channels, may be a fully private good. This distinction has led to the recognition of "basic networks" and "special purpose networks" in hydrometry. This dual nature of water-related information presents significant challenges to governments, in determining the extent to which they should be involved in its provision. A particular concern relates to public access to water-related information that has been collected and is owned by a private agency. The public good attributes of water-related information should tend to encourage governments to take the responsibility for its provision, because the private sector has no incentive to do so. On the other hand, the often long-term and non-specific nature of the benefits, matched against the immediate and readily identified capital and operating expenditures that are required, are a major incentive for governments to under-invest in water-related information.

Table 1 - Arrangements for hydrological services in case study countries

Country	**Basic arrangements for hydrological service**
Austria	The Central Hydrological Office is located in the Federal Ministry of Agriculture and Forestry, with data collection at State level and archiving, analysis etc at Federal level
Brazil	A National Basic Network is administered by the National Electricity Regulatory Agency, with several states also carrying out hydrometry. The National Water Resources Information System is one component of a

	sophisticated National Water Resources Management System, which includes entities at Federal, State, river basin, and municipal levels.
Fiji	The Hydrology Section of the Public Works Department is the only organisation with any significant role in water resources monitoring and operational hydrology (including flood forecasting), although it is not legally constituted as the national service.
Malaysia	The Hydrology Division of the Department of Irrigation and Drainage acts as the national service. Data collection is at State level, with archiving, analysis etc at Federal level.
New Zealand	Hydrology and water resources management are carried out by local government ("regional councils"), and there is no national service. A state-owned research institute maintains an extensive national hydrological network/archive for research and commercial purposes.
Poland	The Institute of Meteorology and Water Management, under the Ministry of Environment, performs hydrological, meteorological, oceanographic and dam technical control services, and manages the warning system for weather and water-related disasters. Other organisations manage water resources, flood protection and management systems, water engineering, etc., and conduct research.
Republic of South Africa	The Scientific Services Chief Directorate of the Department of Water Affairs and Forestry acts as the national service, with wide responsibilities in all aspects of water resources monitoring. The Hydrology Directorate is designated the national hydrological service.
Sweden	The Swedish Meteorological and Hydrological Institute is the national meteorological and hydrological service, and also has responsibility for oceanography. SMHI operates on a commercial basis.
Tunisia	Most aspects of hydrology and water management are carried out by agencies within the Ministry of Agriculture. Hydrological databases are maintained within that ministry, while precipitation data are managed by the National Institute of Meteorology.
Uruguay	The Dirección Nacional de Hidrografía (DNH) is responsible for the national (surface water) hydrological network and National Hydrological Database. A number of other agencies also collect hydrological data for particular purposes or of particular types, and there are several international river basin agencies which acquire water-related data for management purposes.

3.6 Under-investment in the provision of water-related information is generally because a country places a higher priority on expenditure in other areas, particularly health, education, social services, and national defence. There is little to be gained from regretting this state of affairs, or continuing to affirm the value of water-related information in the hope that financial decision-makers will have a change of heart. However, two world-wide tendencies give cause for optimism:

- Application of the concept of Integrated Water Resources Management (IWRM) to managing national and trans-boundary water resources, using the river basin as the fundamental unit of management;
- Incorporation of water resource management into the much broader field of environmental and natural resource management.

Integrated Water Resources Management (IWRM)

3.7 IWRM is being implemented throughout the world to an increasing extent (Annex 2). It recognizes that water must be managed to meet many simultaneous needs, that several agencies with legitimate interests in water often must work together, and that the complexities of the hydrological cycle require a sophisticated approach to make best use of the water. IWRM is commonly taken to include or be linked with the management of soil, vegetation, and land use. It is normally implemented in the context of the river basin, with the establishment of a river basin agency to carry out or oversee the relevant management functions. For example, the Mahaweli Authority has been responsible for the comprehensive development of water resources in the Mahaweli River basin, the largest in Sri Lanka, and basin agencies are being established in other key river basins. In principle, the connectedness of surface and groundwater is often recognised, but in practice most countries are proving rather slow to integrate management of groundwater and surface water, whether in the context of river basins/aquifers or not.

3.8 The European Union Framework Directive on Water Resources Management requires that all members establish basin agencies and develop basin management plans, while the Asian Development Bank is using the river basin as the basis for water sector investment in a growing number of its Developing Member Countries.

3.9 IWRM implies a need for good information about the water resource, to enable the equitable allocation of scarce water among competing users, and to monitor the results of management. Indeed, the adoption of IWRM often is in response to increasing demand for and scarcity of water, and in such circumstances the value of water, and of information about water, needs no demonstration to decision makers. Support for or even advocacy of the adoption of IWRM provides an opportunity for hydrological services to promote an environment that is "friendly" towards their functions. Nevertheless, it should be recognised that in many countries policy development, civil administration, and environmental management are undertaken by entities whose boundaries frequently are unrelated to river basins. Hence, the overall governmental environment still may be less than ideal for effective water resources management at the river basin level.

3.10 Adoption of IWRM and establishment of a river basin agency may bring institutional change that has a significant impact on hydrological services. At the very least, it requires hydrologists to develop a clear understanding of the needs of *all* their customers, and a willingness to "do different things and do things differently", in order to meet those needs. Negative effects have been experienced in some countries, such as the division of a national hydrological service into several units each of which serves a river basin agency but which does not have the critical mass to carry out all necessary functions. Related consequences may be duplication of effort, especially in research and development, a loss of national standards of practice, and difficulty in compiling national information about the water sector. International exchange of experience is highly desirable, to avoid such dangers. Experience on arrangements that enable effective decision making, simultaneously at local, regional and national scales, is of particular interest.

Environmental and natural resource management

3.11 Many governments are responding to the urgent need to conserve their countries' deteriorating natural resources and environment, by establishing agencies with wide-ranging responsibilities for resource and environmental management. Water resources normally are included, and indeed are often a core element of the agencies' responsibilities.

3.12 As with IWRM, the need for a good information base to support environmental and natural resource management is obvious to practitioners (if not to elected officials and the public), and research and investigations commonly are key functions of environment and natural resource agencies. This does not, of course, ensure that adequate financial resources will be forthcoming, but it does mean that an institutional environment exists in which the traditional functions of hydrological services are regarded with favour. To an even greater extent than with IWRM, however, hydrologists will find themselves called on to "do different things". The traditionally dominant activities of river flow gauging and rainfall monitoring are likely to become *relatively* less important, as information on water quality, aquatic ecosystems, river corridors, water demand, etc. is demanded by analysts and decision makers. Hydrologists in many countries have found themselves spending less time on their traditional activities, as they develop skills in new areas and learn how to "do hydrology" more efficiently.

3.13 Such an environment of change can be extremely threatening, but opens up new opportunities for hydrological services to apply their distinctive capabilities more widely. Many areas of environmental management are only now developing the tradition of careful data collection and analysis that has long been characteristic of operational hydrology. Hydrologists might well welcome the opportunity to become part of an environmental agency, even though the visibility of hydrology as a distinct discipline may be lessened.

4. NATIONAL HYDROLOGICAL SERVICES: ROLE, FUNCTION, AND MISSION

Sources of guidance

4.1 The WMO already has provided a substantial amount of guidance with respect to the role and functions of hydrological services, and reference should be made to the following documents for detailed information:

- *Guide to Hydrological Practices* (WMO, 1994a), chapter 3 – Hydrological Services
- *Technical Regulations* (WMO, 1988), Volume III – Hydrology
- *Water resources assessment: Handbook for review of national capabilities* (WMO/UNESCO, 1997)
- *The legal basis and role of hydrological services* (WMO, 1994b)
- *Casebook of examples of organization and operation of hydrological services* (WMO, 1977)

4.2 The last two give specific case studies on the legal and organizational basis of hydrological services in several countries, and the 1994 publication in particular might be used to identify places from which more detailed guidance or examples might be sought.

Water-related information needs

4.3 Conventionally, the role of a hydrological service is defined in terms of knowledge or information about water (following the original Greek roots of the word "hydrology"). A distinction therefore may be made with respect to agencies that have responsibility for managing water. Some countries have organizations whose role is restricted to generating hydrological information. However, in many others the same agency (or, frequently, several agencies) *gathers the information about* water that it requires to fulfil its responsibilities to *manage* water, and many hydrological services originally were established for a very specific purpose, such as to provide design data for a hydroelectric development programme. This feature distinguishes many hydrological services from National Meteorological Services, whose role has tended to be much more focussed on the provision of information services, with other organizations making use of that information.

4.4 Broadly, the water-related information provided by a hydrological service is required for (WMO, 1994):

- Assessing a country's water resources, the potential for water-related development, and the ability to supply actual or foreseeable demands;
- Planning, designing and operating water projects (including navigation);

- Assessing the environmental, economic and social impacts of water resources management practices, existing and proposed, and adopting sound policies and strategies;
- Assessing the impacts on water resources of other non-water sector activities, such as afforestation;
- Informing and educating the public and decision-makers;
- Providing security for people and property against water-related hazards, particularly floods and droughts.

4.5 These requirements imply the provision of data and information about past, present, and future conditions. While the primary focus of a particular hydrological service may be its own country, hydrological services in countries which share international river basins may also have a responsibility to provide information to other countries or to an international river basin agency.

4.6 Depending on the particular circumstances of each country, specific information needs differ widely from country to country. For example, one country might have a particular need for information on total water yields, summer low flows and flood peaks, to enable design of hydro-electricity schemes and irrigation systems. Another, with an extensive heavy industrial sector, might need information principally on surface water quality and the status of groundwater aquifers, to safeguard water resources in the face of heavy consumption or contamination of water by industrial enterprises. Because of the continuously changing pressures and demands placed on water by the community, it is inevitable that information requirements also are continually changing, which requires each hydrological service to regularly re-evaluate its information products and services.

Typical activities required to provide water-related information

4.7 The activities involved in obtaining water-related information and providing it to users include (WMO, 1994):

- Establishing the requirements of present and future users for information;
- Defining the attributes (accuracy, etc) of data and information necessary to meet those requirements;
- Designing and establishing use-specific and basic hydrometric observing networks;
- Developing methods for transferring information from measurement sites to other locations;
- Collecting data and maintaining quality control over data collection procedures;
- Processing the archived data and maintaining control of the quality and security of data;
- Making the data accessible to users when, where, and in the form that they require. This implies transformation of data into information, and may include provision of warnings, either directly or to civil defence agencies;
- Informing potential users of the data and information that are available, and assisting them to make the best use of them;
- Developing new technology and developing and training staff;
- Carrying out research into hydrological and related processes to assist users to interpret and understand the information;
- Ensuring co-ordination with other agencies that acquire water-related or other relevant information.

In practice, many hydrological services have dealt primarily with surface water resources, and groundwater information (but rarely groundwater management) has been the responsibility of a national geological survey. As a result, the above activities have been carried out in parallel by two (or more) agencies in many countries, which is a considerable impediment to effective management of what is, in fact, a single resource.

Mission statement

4.8 Many organizations see a benefit in developing a mission statement that encapsulates their role in an understandable and memorable way. A mission statement is seen as succinctly expressing the long-term, core business and values of the organization, which are expected to remain largely unchanged even though many aspects of the business environment may be changing. A clear mission statement should assist:

- the hydrological service to establish its core business, clients, priorities, and values;
- clients (including the government) to have accurate expectations of the hydrological service;
- the government to determine appropriate levels of funding;
- other organizations to define their own relationships with the hydrological service.

4.9 In some countries, the hydrological service may have a mission statement that is enshrined in legislation. In this case, the statement will probably provide the substantial advantage of a legally established mandate. In other countries, there may not be an independent hydrological service as such, and water-related information may be collected by a unit within a larger organization, such as the Irrigation Department or Ministry of Public Works. It would still be beneficial for the unit to develop its mission statement, but the legal mandate may be extremely brief, or completely lacking.

4.10 It is inappropriate to provide specific guidance on the possible elements of a mission statement, because of the diversity in the roles, legal bases, and institutional arrangements for hydrological services. However, some key elements might be, where relevant:

- protection of life and property;
- a focus on customers and beneficiaries, for example in terms of a contribution to national goals for sustainable social and economic development;
- meeting international commitments, particularly in shared river basins.

5. NATIONAL HYDROLOGICAL SERVICES: INSTITUTIONAL ARRANGEMENTS

Models for the organization of hydrological services

5.1 In a survey of 67 countries carried out in 1991 (WMO, 1994a), four principal models were found for organizing hydrological services at the national level**:**

National hydrological or hydrometeorological agency(ies) only:	51%
Regional (sub-national) hydrological or hydrometeorological agencies only:	1%
Both national and regional hydrological or hydrometeorological agencies:	42%
Neither national nor regional hydrological or hydrometeorological agencies:	6%

5.2 It is probable that these percentages have changed since 1991, and a repeat survey would be very desirable.

5.3 In 1991, only a minority of countries had a single national service whose principal role was operational hydrology, while several had a national or federal organization principally responsible for research, but not for the full range of functions included in operational hydrology. In many countries listed as having a National Hydrological Service, the agency had a broad range of functions, only one of which was operational hydrology. Common links were with public works, environment, or water resources management. Commonly, operational hydrology functions were located in several agencies, each of which required hydrological information in support of their principal responsibilities of irrigation management, power generation, etc. One of these may have been the "lead agency". In some countries, the lead agency assisted or co-ordinated regional/provincial agencies that carried out operational hydrology in their jurisdictions.

5.4 Arrangements for ensuring that data collected by multiple agencies are exchanged and disseminated varied widely. In some cases, the lead agency had a formal, statutory coordinating role. Frequently, a separate body had been established (in some but not all cases by statute) to ensure coordination. In many countries, there appeared to be difficulties in ensuring coordination, integration, and the maintenance of common standards that enable data to be compared with confidence. Increasingly, limitations on data exchange appear to be experienced, as agencies decline to transfer data that they own, or charge unrealistic prices for data.

5.5 As discussed earlier, there is a strong trend towards establishing river basin agencies that have comprehensive responsibilities for water management, including the provision of the water-related information that they require. Such agencies now can be found on every continent. In several cases, these river basins and their agencies are trans-national, like the Zambesi River Authority in Southern Africa. Some countries have complete coverage of river basin agencies, others have agencies only in the principal river basins.

5.6 In summary, there is great diversity in the organizational arrangements for hydrological services, and arrangements also are undergoing change in many countries. No common relationships with legal system, governmental system, language, or stage of economic development are evident. However, apparently successful examples of each model can be seen, which suggests that effective operational hydrology can be achieved in a variety of circumstances.

5.7 Nevertheless, there is a strong international consensus that integrated water resources management, based on the river basin and with some form of river basin agency, is the preferred model. Annex 2 summarizes relevant statements from several international organizations and recent fora, which support this.

The legal basis of hydrological services

5.8 The legal bases of hydrological surveys were found, by the survey in 1991 (WMO, 1994b), to be as diverse as their institutional arrangements. However, almost all countries have hydrological services that:

- Have been explicitly established by a statute, decree, or order (depending on the system of government); or
- Carry out functions that are provided for or enabled by legislation, although the legislation does not establish a specific agency; or
- Have been set up within a government agency that requires hydrological information in the process of discharging its responsibilities. Their authority comes, in effect, from an annual appropriation of funds.

5.9 The services may (and in most cases do) themselves carry out all the functions included within the traditional definition of operational hydrology, or they may contract some part out to other organizations, if that is more efficient.

5.10 Increasingly, there has been a tendency for legislation to deal with water resources management, or the environment as a whole. The complementarity of surface water and groundwater increasingly is recognised. The emphasis tends to be on regulatory aspects of water resources management, such as water allocation among competing users and administration of permits (rights, consents) to use water or waterways in some way. Operational hydrology may be dealt with briefly, if at all.

5.11 An institutional model found in several countries is the state-owned corporation. It is responsible under statute to a particular minister and is required to operate on a commercial basis, possibly providing a dividend to its minister as well as providing services under contract to its public and private sector customers. Frequently, such a corporation was formerly a government department, but its functions were seen as more appropriately carried out in a commercial environment.

Commercialisation in hydrology

5.12 The 1991 survey referred to above (WMO, 1994b, p. 7-8) reviewed the extent of commercial practices among Members' hydrological services. Arrangements were found to be changing rapidly at that time, and it would be very desirable to repeat the survey to accurately assess current practice. Services could be placed along a continuum stretching from wholly funded by government appropriation at one end, through to wholly reliant on commercial activities at the other. (In the latter case, government contracts might nevertheless make up the bulk of the revenue).

5.13 Almost invariably, government agencies provide from general taxation the "traditional" hydrological products and services, such as water resources assessment and flood warning, that are public or social goods. Increasingly, the costs are recovered of services that are not fully public or social goods, where users can be readily identified, for example preparing, reproducing and mailing a specifically requested list of data. In this case, direct costs are usually recovered, although some agencies also attempt to recover a portion of the costs of their basic data collection and management.

5.14 Added value services that have private good characteristics have long been a feature of hydrological practice. An example might be the analysis of hydrological records in a river basin to provide flood frequency information required for design of a large dam. They have commonly been supplied on a full cost recovery basis by governmental organizations, or on a fully profit-making basis by private sector organizations.

5.15 There is no reason in principle why basic hydrological products and services cannot be purchased by the state from a private sector organization, or from a state-owned enterprise established for the purpose. This model is being used in an increasing number of countries, for instance by contracting out some hydrometric data collection functions. It may provide "market discipline" to and greater control over the provision of public hydrological services. On the other hand, where public safety or the public interest is an issue, arrangements must ensure that hydrological products are free from bias, and are not manipulated for commercial advantage.

5.16 The legal arrangements for the commercial and semi-commercial activities of hydrological services often have been rather ill-defined, with practice established through budgetary means or by ministerial directive. However, the use of purchase agreements (quasi-contracts) between minister and head of service, or the establishment of a state-owned enterprise which supplies services on contract, increasingly are placing arrangements on a well-defined basis which can greatly assist budgeting, planning, and performance evaluation.

6. THE SUSTAINABILITY OF HYDROLOGICAL SERVICES

6.1 As governments world-wide seek opportunities to reduce expenditure, such traditionally low-profile activities as the provision of water-related information are a prime target for budget reductions. The public good attributes of much hydrological information – for instance, its particular benefit to future generations of engineers and analysts rather than to the present-day voting public, the lack of a specific customer for information from a "basic network", the focus of much water-related information on environmental and natural resource issues (which are inherently public goods) – mean that there may be few advocates for the adequate funding of hydrological programmes.

The value of water-related information

6.2 The *applications* of water-related information were introduced in earlier sections. The *value* of such information is essentially that it:

- Reduces the costs of decision-making, by enabling decision makers to act with greater confidence and less risk of error;
- Reduces the costs of unduly conservative, incorrect, or inferior decisions;
- Maximises the social and economic value of a water resource, by facilitating more precise management of the resource.

6.3 Unfortunately, the relevant costs and values frequently cannot readily be expressed in monetary terms, so that benefit-cost analyses that (improperly) consider only monetary benefits and costs do not give them appropriate weight. For example, the future cost of over-designing a dam spillway because of a paucity of hydrological data, or of building an irrigation scheme in which "tailenders" rarely receive water because the resource was incorrectly estimated, is rarely considered by treasury officials concerned to minimise *this* year's budget deficit. The costs are, unfortunately, relatively greatest in developing countries, which can least afford them. In comparison with the hard-to-define benefits of water-related information, the ongoing costs of obtaining that information are only too obvious to those with responsibility for balancing budgets.

6.4 The WMO already has provided extensive guidance on how to identify the economic and social benefits of meteorological and hydrological services, based on the results of relevant research stretching back over 30 years (e.g. WMO, 1990). Benefit-cost ratios for hydrological data needed for specific projects are typically in the range 5-10 (WMO/UNESCO, 1998). Estimates of the relative benefits and costs of basic networks are not so readily available, although the results of WMO conferences on the economic benefits of meteorological and hydrological services indicate ratios up to 10:1 or even higher. However, such general figures do not appear to be persuasive with financial decision-makers, and they cannot be used to advocate investment in meteorological and hydrological services without more specific justification.

Evolving societal needs for water-related information

6.5 The earlier discussion of IWRM and environmental/natural resources management points to a need for hydrological services to respond to changing community needs. Hydrologists cannot realistically expect to continue only with their traditional areas of work, if the community and its political representatives consider that there are additional or higher priorities. Therefore, while hydrologists continue to seek to deliver existing hydrological products and services, they should also seek new ways of presenting them and tailoring them to meet new needs. Hydrologists should seek also to develop new products and services in non-traditional areas, for example relating to the fast-growing fields of ecohydrology, ecotourism, and water-based recreation. In this respect, they can learn from the recent efforts of the meteorological community to respond to evolving societal demands for weather information that is directly relevant to specific areas such as sport, or human health.

Alternative models of service delivery

6.6 Earlier sections have shown that the institutional, legal, and commercial arrangements for delivering hydrological products and services are very diverse. It would be inappropriate to recommend particular arrangements, because successful examples of all types can be cited, from the wholly commercial to the wholly funded by government appropriation. In any case, the officials of hydrological services may have limited control over the arrangements under which they are required to work, and which are established in the context of broader policy on governance and public administration. There appears to be a world-wide trend towards requiring a more commercial approach to the provision of water-related information, and hydrologists may be well-advised to work on the assumption that this trend will continue. The case studies assembled in WMO publications may be of benefit to the officials of particular services who are seeking guidance; indeed, it would be beneficial to regularly update them.

6.7 Whatever the institutional arrangements in a given country, some general suggestions might be offered:

- Hydrological services should seek, where appropriate, to apply the management practices of well run organizations, both public and private, in financial management, personnel management, risk management, and other areas of their operations. Where possible and not already required, senior managers should seek to establish some form of service delivery agreement or contract with the relevant authority, to provide a clear basis for performance appraisal and specification of future funding requirements. The adoption of accrual accounting may facilitate asset management and replacement, since it becomes obvious under this method whether the physical assets of a service are being maintained, or run down.
- Hydrologists should adopt a "market-led" approach to their business, in which they are well informed of and promptly respond to the evolving needs of their clients. They should recognise that maintenance of a "traditional" archive of basic hydrological data, with no added value, has limited interest to the public and their representatives.
- Hydrologists should be ready to move into new areas of work if society's expectations demand it, and should even be prepared to relinquish traditional areas if they have reached the "point of diminishing returns" at which resources would be better directed elsewhere.
- At the same time, hydrological services should continually seek ways and opportunities to demonstrate the value of their products and services to society, particularly by direct contact with key decision-makers. They should assemble information, preferably in co-operation with civil defence and other relevant agencies, that documents the benefits of their services. Above all, they should recognize that their strongest advocates are likely to be clients who are well satisfied with the service they have received.
- Where permitted to do so, hydrological services should actively seek to develop their opportunities to recover costs from water users and to develop commercial products and services, while scrupulously avoiding the neglect of the public and social services that they provide.
- Hydrological services that are engaged in commercial or cost-recoverable work should develop clear policies and effective working relations with other organizations with which they might collaborate or compete, to ensure that their activities are consistent with generally accepted rules of the market.
- Hydrologists should respond positively to moves to introduce Integrated Water Resources Management, or to introduce comprehensive environmental and natural resources management. Even though these may bring significant organizational restructuring, they are likely to provide opportunities to extend the scope of hydrological activities, and develop effective relationships with other disciplines. An aspect of IWRM is the need to integrate the management of surface and groundwater to a much greater extent than has commonly been the case.

International aspects of hydrological services

6.8 National arrangements for the provision of hydrological services in most cases do not depend on the international exchange of information to the same extent as for meteorological services. Nevertheless, the international dimensions of hydrology are becoming increasingly evident:

- There are several hundred significant international river basins, in many of which increasing pressure on water resources is demanding heightened levels of co-operation and information exchange. Potential benefits of international interaction also are being recognized in other circumstances – among countries whose rivers drain into a single marine area (most obviously, the Mediterranean and Baltic), or which have very similar climatic regimes and limited individual resources for R&D (for example, the Caribbean and SW Pacific areas).
- Efforts to understand the global climate system are requiring improved information on the global water cycle, for example as inputs to regional and global models being developed under GEWEX. In turn, they are providing new tools for hydrologists, for instance in seasonal flow forecasting.
- There is significant investment in international data systems, such as the Global Runoff Data Centre and GEMS-Water.
- The increasing sophistication and expense of hydrological technology are forcing a greater level of co-operation and exchange among hydrological services, which simply cannot afford to rely on their own resources.
- Intergovernmental responses to global issues, in the context, for example, of the Commission for Sustainable Development, are providing unprecedented opportunities for contacts among hydrologists from different countries.

6.9 In response to growing major environmental issues of regional and global concern, there are increasing demands and requirements for the international exchange of hydrological data and products. The Thirteenth World Meteorological Congress, meeting in Geneva in May 1999, adopted Resolution 25 (Cg-XIII) – Exchange of hydrological data and products, thus establishing a policy and practice for the international exchange of hydrological data and products. This policy will facilitate the meeting of these demands through the co-operation of the Member countries and will benefit society, the economy and the environment. With the adoption of this new policy by Congress, WMO has committed itself to broadening and enhancing, whenever possible, the free and unrestricted international exchange of hydrological data and products, in consonance with the needs of the global hydrological community and the requirements for WMO's scientific and technical programmes

6.10 The WMO is responding, by providing opportunities for transfer of technology and knowledge, and facilitating collaboration. These include:

- Supporting the capacity building of services, especially in the area of management, for example by including hydrologists in appropriate training events and seminars.
- Promoting and facilitating the exchange of hydrological technology, through HOMS.
- Arranging for exchange of experience, both through formal mechanisms such as meetings of Regional Associations and through more informal mechanisms such as visits to other services.
- Promoting and supporting international collaboration among services, particularly in the context of shared river basins, through such vehicles as the WHYCOS initiative.
- Informing governments of the environmental, economic, and social benefits afforded by hydrological services, and providing services with appropriate resource material for this purpose.
- Adoption and promulgation of Resolution 25 (Cg-XIII) on the international exchange of hydrological data and products.

6.11 The amount of assistance that the WMO Secretariat is able to provide is severely limited by the level of resources that are committed to the Hydrology and Water Resources Programme. Efforts are therefore made to collaborate with other international organizations with water-related programme, including the UNESCO International Hydrological Programme, the Global Water Partnership, and the International Network of Basin Organizations. Unfortunately, hydrologists in most countries do not have the time to maintain links with all such organizations.

7. CONCLUSION

7.1 The critical importance of water to human life and the biophysical environment is firmly established in international thinking. So too is the need for reliable information on which to base wise management decisions, although the need for adequate funding of that information is less well accepted. In these circumstances, hydrological services *should* have an advantage in terms of demonstrating their contribution to society. That hydrological services commonly have been established in response to a specific need may be an advantage, but also can be an obstacle to change where that original need has become less relevant to current circumstances.

7.2 Hydrological services the world over are being required to “do more with less”, in common with most other public agencies. In some parts of the world, the hydrological services are under-funded to such an extent that they have limited ability to deliver the products and services that they know could provide huge benefits to their countries. And in many countries, evolving theories of public administration are bringing significant changes to the environment in which the hydrological services function.

7.3 There are a number of trends that give some cause for optimism, although hydrological services in some countries with particularly weak economies may see little comfort in them. These trends include those towards acceptance of Integrated Water Resource Management as an effective model for management, the centrality of water in environmental and natural resource management, the internationalisation of hydrology, and the introduction of commercial approaches and good business practice to public sector management. These trends might all be seen as threats, but they can also offer opportunities to hydrologists to strengthen the position of their work. The range of institutional, legal, and commercial arrangements under which hydrological services currently operate is so diverse that no particular model can be offered as the preferred one. Nevertheless, some key principles have been suggested that may assist hydrologists to respond to the changing environment. There are several areas in which WMO already assists hydrological services, outlined in the preceding section. However, there is a growing list of organizations that are active in the water field, which presents difficulties for national hydrological services. It is very desirable that WMO establishes itself quite clearly as the leading international organization that provides support to hydrological services.

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ANNEX 1

COUNTRY CASE STUDIES

Austria[3]

Background

The Federal Republic of Austria has a total area of 84,000 km^2, two thirds of which is in the Eastern Alps of Europe. Land use is 42% forest, 27% pasture, and 20% arable; the population is about 8 million. The water balance of Austria shows it to have abundant supplies of freshwater:

- Mean annual precipitation: 1170 mm
- Mean annual runoff: 654 mm
- Domestic withdrawal: 8 mm
- Industrial withdrawal: 20 mm
- Agricultural withdrawal: 2 mm

However, as with most developed countries, the quality of water – both surface and sub-surface – has become of increasing concern, and this concern has been reflected in recent environmental legislation.

Arrangements in Austria for water resources management and hydrology strongly reflect the status of the country as both a confederation and a member of the European Union, as well as the long history of meteorology and hydrology. The Central Hydrological Office was founded in 1893, while the Meteorological Service was created even earlier, in 1875. This long history, together with recognition of the need for good information to care for the nation's environment, no doubt have contributed to the development of an extensive observing network, which includes about 5,000 stations monitoring everything from precipitation and snow depth to ground water temperature.

The legal basis of hydrology and water resources management

Water resources management is carried out by the Provincial Governments, under the provisions of the Water Act. Municipalities have responsibility for water supply under the same Act. The Water Act and the Hydrography Act (1979) are the principal statutes under which water and water quality are managed. The European Framework Directive on Water Management will increasingly guide statutory arrangements, as it comes into force.

Hydrology, in the sense of evaluation of the water cycle, is carried out within the framework of the Hydrography Act. This enables the Federal Minister of Agriculture and Forestry to assess the physical status (including sediments, ice, temperature) of surface and groundwaters, working through the relevant authorities in the Provincial Governments. Flood warning is a Provincial responsibility, under the Hydrography Act (Section 7). One of the most significant provisions of the Hydrography Act is its requirement for other organisations, such as electricity generators, to provide hydrometric data to the Hydrological Service.

The Environmental Information Act (1993) establishes requirements on government agencies for making environmental information freely available; it relates in particular to information on water quality. The Act reflects the requirements of the European Directive 90/313/EEC, *Free access to environmental information*.

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[3] The assistance of Franz Nobilis (Bundesministerium für Land- und Forstwirtschaft) is gratefully acknowledged.

Institutional arrangements

A full range of hydrological functions are carried out by the Hydrological Service in Austria – the Service consisting of the Hydrological Divisions of Austria's nine Provincial Governments, and the Central Hydrological Office located in the Federal Ministry of Agriculture and Forestry. Functions include:

- Survey of the water cycle
- Coordination of observation networks
- Hydrological investigations relating to construction and water management
- Water level reporting and flood forecasting/warning
- Data archiving and analysis; publication and dissemination of information.

Water quality monitoring also is carried out under the authority of the Hydrography Act. The Provincial Governments are responsible for contracting out water sampling and analysis, to private laboratories. The Federal Ministry of Agriculture and Forestry (Water Management Registry) is responsible for technical management and coordination at the federal level, funding (all establishment costs and 2/3 of the total operating cost), and data flow. The Federal Environment Agency is responsible for data archiving, coordination, analysis and interpretation of the data, and for publication. Publications include yearbooks, various maps and reports on water quality trends, and the bi-annual *State of the Environment Report*, which is presented to Parliament.

The Meteorological Service, located in the Ministry of Research and Transport, operates a synoptic and climatological network of over 300 stations, that observe all the standard meteorological variables.

In total, then, the observing network in Austria amounts to:

>300	climate and synoptic stations
800	precipitation gauges
840	snow depth gauges (included in the preceding two items)
790	water level gauges
670	flow measuring stations (included in the preceding item)
2900	ground water level gauges
2020	groundwater quality sampling sites (4 observations/year)
240	river water quality sampling sites (>12 observations/year) (the sampling programme is to be extended to lakes)

In addition to Federal and Provincial Government activity, private sector organisations, principally hydro-electric power companies, collect hydrometric data, and are legally required to provide them to the Hydrological Central Office. As already noted, the extensive water quality sampling programme also is carried out by the private sector, with public funding.

Hydrological research by universities and research institutes includes the operation of experimental work, theoretical work, and projects of operational value on contract to both the public and private sectors.

At the moment, the Minister for Women's Affairs in the Federal Chancellery is responsible for food and drinking water standards. The Minister for Work and Social Affairs is responsible for public health, and therefore for bathing water standards.

Relationship between meteorology and hydrology

The Meteorological Service and Hydrological Service are located in different federal ministries, and have complementary functions. There is a formal arrangement for the two heads of the services to meet twice a year, to discuss any issues relating to the observing networks and other matters.

Policies on data transfer and exchange

All data concerning the water cycle are defined, by the 1999 amendment of the Hydrography Act, as data subject to the Environmental Information Act. They are therefore required to be transferred on request at no more than the marginal costs of supply, where published in the hydrological Yearbook and other publications of the Hydrological Service. For internal data, whether original or processed, there is no legal obligation for the Hydrological Service to provide them. In practice, they are given to contractors who are working on governmental contracts.

The legal status of the Meteorological Service is somewhat different, as it is enabled to charge for its information products, and therefore sells data, when possible to do so while still conforming to WMO Resolution 40.

Both organisations provide data for research applications, at no charge except for direct costs of transfer. No distinction is made between data transfers within the country, and internationally.

Summary and assessment

Austria has a National Hydrological Service with extensive responsibilities for water-related data collection, mandated principally under the Hydrography Act. Austria has a federal system of government, and the Hydrological Service has a structure in which data collection and initial processing is carried out at provincial level, and data archiving and dissemination is predominantly at federal level. The Hydrological Service, which is located in the Federal Ministry of Agriculture and Forestry, collaborates with other agencies in a number of areas of its work, including the Meteorological Service and the Federal Environment Agency.

The status of water resources assessment and operational hydrology in Austria is satisfactory, and the extent of the observing networks and the public accessibility of hydrological data and environmental information is among the best in the world. The clearly defined functions of governmental bodies, and the availability of data at no more than direct costs of transfer, ensure economical provision of information. As is universally the case, however, hydrological specialists recognise a need for additional resources to maintain an adequate observing network, particularly to provide real time data, and an adequate corps of staff to carry out data management, analysis, and interpretation.

Brazil[4]

Background

Hydrological survey in Brazil began over a hundred years ago, when the first rainfall measuring stations were installed. Later, a start was made on establishing water level and flow monitoring stations, in order to support demands for developing hydropower. From the beginning of the 20th Century, the hydrological services were handled in a more organised manner, gradually developing in terms of both operating methodology and the locations monitored.

More recently, sweeping changes are underway, prompted by new technology which streamlines fieldwork and enhances the quality of the information that is gathered. At the same time, a new awareness is developing at the State level of the importance of hydrological monitoring, so that each State can understand and manage its own resource. At the Federal level, the importance of maintaining a well-planned and operated hydrometric network is increasingly recognised. This is seen as needed to ensure proper management of Brazil's water resources, and meet the demands of the public and private sectors for information in support of transportation, agricultural, energy, public health and other infrastructural developments.

The legal basis of hydrology and water resources management

The Water Code was enacted in 1934, through Decree 24,643. It became an important tool for the development of the nation's hydropower sector, in terms of studies of hydropower projects and hydrological measurements made by the Water Resources Division. The Ministry of Mines and Energy was established in 1960 through Law No. 3,782. It absorbed all the agencies in the National Mineral Production Department, including the Water Resources Division. With later restructuring of the Ministry, the Water Resources Division was transformed into the National Water and Energy Department (DNAE - later the National Water and Electric Power Department); hydrological activities were decentralised to eight new Districts. Later, the Department worked closely with the U.S. Geological Survey to expand its expertise and streamline its structure. A milestone in modernisation was the introduction of the Hydrological Information System, with computerised hydrological data processing.

Decree-Law No. 764 established the Mineral Resources Survey Company in 1969, which contracted the DNAE to operate and maintain its hydrometeorological stations. In 1996, the DNAE was closed and the Brazilian Electricity Regulatory Agency was established, through Law No. 9,427. There is a transition period during which the Agency is responsible for the hydrometric network, but future institutional arrangements for hydrometry are yet to be defined.

Institutional arrangements

Brazil's 1988 Federal Constitution establishes that "lakes, rivers and any other watercourses on land owned by the Federal government are assets of the Union as well as the ones which run through more than one state, or serve as borders with other countries, or extend into foreign territory, or flow therefrom, and also their banks and river beaches."
It also establishes that "the assets of the States include surface or underground waters, flowing, emerging and stored, with the exception in this case and in form of law of those included in the undertakings of the Federal Government."

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[4] Prepared by Mr Roberto Coimbra, Brazil

The Federal Government, the States, the Federal District and the municipal districts are jointly responsible for protecting the environment and combating pollution in any form, fostering improvements and supervising exploitation rights awarded for water resources in their respective territories, legislating concurrently on the protection of land and natural resources, environmental protection and pollution control, liability for environmental damages, and the protection or defense of health.

The National Water Resources Policy was introduced by the Water Law (Law No. 9,433 of 1997), which established the National Water Resources Management System and amended Item XIX of Article 21 of the Federal Constitution. The culmination of a lengthy process of assessing water resource management experiments and formulating proposals to upgrade water management in Brazil, this law is a historic milestone. The National Water Resources Policy includes the following sections:

- Bases: the foundations on which the Policy is structured
- Objectives: the targets to be achieved
- Action Guidelines and Tools: the means by which the Objectives are achieved.

The Water Law establishes the following Bases:

- Water is an asset in the public domain
- Water is a limited natural resource which has economic value
- The priority uses of water are human consumption and livestock watering
- Water resource management should ensure multiple use
- The river basin is the territorial unit for water policy and management
- Water resource management should be decentralised, and involves the government, users/stakeholders, and communities

The Tools include Water Resources Plans, the Water Issuance Warranty as a way of ensuring and controlling usage rights, fees for water use, classification of water bodies according to their main uses, financial compensation of municipal districts, and the National Water Resources Information System.

Water Resources Plans provide a guide for implementation of the National Water Resources Policy, in addition to long-term water resources management with planning horizons compatible with the implementation periods of its programmes and projects. They assess the current status of water resources, analyse social and economic dynamics, identify potential conflicts, develop usage targets and implementation plans, establish guidelines and criteria for usage fees, and specify measures to protect water resources. Master Plans are developed with river basins as the planning unit, and State Plans and a National Water Resources Plan also will be developed.

The National Water Resources Information System for collection, processing, storage and retrieval of water resources and related data is contributed to by entities belonging to the National Water Resources Management System. Its objectives are: gathering, collecting and disseminating data and information on the quality and quantity of water resources; constant updating of information on water availability and demand; and providing feedback for preparation of Water Resources Plans. Its basic principles are:

- Decentralisation of data and information uptake and production
- Unified co-ordination
- Guaranteed broad access to data and information for society at large

The Water Issuance Warranty stipulates that the following uses of water must be enabled by the government:

- Abstraction for consumption, including public water supplies, and as input for production processes
- Dilution, transportation or final disposal of treated or untreated sewage and other liquid or gaseous wastes
- Construction of hydropower plants
- Other uses which modify the water flow system or the quantity or quality of water

Water Issuance Warranties are awarded by competent authorities belonging to the Federal Executive, the States, or the Federal District. The Federal Government is required to reach agreement with the relevant States and/or Federal District when awarding water usage rights in river basins whose waters are under Federal and State domain.

Water classification is designed to ensure water quality compatible with the most demanding uses for which water is intended, and to reduce the costs of managing water pollution. Water body classes are defined by the environmental legislation.

Fees are charged to recognise water as an economic good, give users an indication of its real value, encourage rational water use, and provide funds to finance the programmes and projects included in Water Resources Plans. Fees are charged for water resource uses subject to the Water Issuance Warranty, and preferably are invested in the river basin in which they are generated.

The objectives of the National Water Resources Management System are to:

- Co-ordinate integrated water resources management
- Resolve conflicts relating to water resources at the administrative level
- Implement the National Water Resources Policy
- Plan, regulate and control the use, preservation and recovery of water resources
- Introduce fees for water resource use

It includes the National Water Resources Council, State and Federal District Water Resources Councils, River Basin Committees, Water Agencies, and federal, state and municipal agencies whose responsibilities are related to water resources management.

Relationship between Meteorology and Hydrology

The National Meteorological Services are under the administration of the Ministry of Agriculture. Data series extend back for more than 100 years. The relationship with the hydrological services is well developed.

Policies on data transfer and exchange

Mot hydrological data are available upon request and free of charge. Data from the Brazilian Electricty Regulatory Agency are available via the Internet at www.aneel.gov.br, including real-time data transmitted via satellite. Water resources information including legislation, water issuance warranties, master plans, inventories etc also are available from the Water Resources Secretariat and the Ministry of the Environment via Internet, at www.mma.gov.br and www.snirh.gov.br

Assessment

Several States in Brazil carry out hydrological data surveys; some such as Paraná and Saõ Paulo have a long tradition in this field. These supplement the National Basic Network, today operated by the National Electricity Regulatory Agency. In 1998, there were 11,100 hydrometric stations in Brazil, costing US$18.5 million to provide information vital for the agriculture, transportation, health and energy sectors, as well as for civil defence and public safety. Operating funds come from levies on the hydropower sector for the use of water for power generation, and from state and federal budgets.

More information is available in *The state of water in Brazil* (1999), published by the National Electricity Regulatory Agency and the Water Resources Secretariat.

Fiji[5]

Background

The Fiji Islands include over 300 islands dispersed over 141,800 km^2 of tropical, territorial waters. The two main islands, Viti Levu and Vanua Levu, together have a land area of 18,272 km^2 and support the majority of the population of around 775,000 (1996 census). The urban population wa 46% in 1996, but Fiji is heavily dependent on agriculture, with sugar being the major industry. Tourism and the hospitality industry follow. Some manufacturing with garment industries, forestry and mining are developing. The average rainfall of 2.5m over the islands provides 1,800 million m^3/year, but rainfall is highly seasonal, and a single cyclonic storm (usually in the wet season) can produce up to a metre of rain in a day or two. Severe floods and droughts are common, and the experience of the 1997/98 drought and flash floods in 1999 has prompted calls for strong mitigation measures. Management of water resources to deal with competition and mitigate the effects of floods and droughts is essential.

The Sustainable Development Bill before Parliament will, it is envisaged, promote comprehensive changes in water management, in the near future.

The legal basis of hydrology and water resources management

There are several pieces of water resources legislation that are outdated but have served well. The principal ones are the Rivers and Streams Act (Cap 136), the Water Supply Act (Cap144) and the Sewerage Act (Cap 128). There is no legal mandate for operational hydrology.

The Sustainable Development Bill (SDB), which bears some similarities to the New Zealand Resource Management Act, is presently before Parliament. Its concept is basically sustainable development i.e. development which does not deplete natural resources or destroy the environment. It draws on existing legislation on various topics, retains the statutory roles of existing ministries in respect to the environment, but coordinate them. The Asian Development Bank provided much encouragement for the government to produce a single coherent piece of legislation which will draw together and update various laws intended to protect the environment and to manage natural resources. There will still be no single authority responsible for hydrology and water resources management in Fiji, but the activities of all individual statutory bodies will be coordinated by the National Council on Sustainable Development through the Directorate of the Environment.

When the SDB comes into force, institutional arrangements, government policies and legislation are likely to change. Monitoring of all resources including water will have to be undertaken, to meet the stipulated requirement of publishing a National State of the Environment every five years. Regular sustainable development audits of those ministries, departments and statutory bodies that are required to implement a system of natural resource accounting will have to be undertaken. The Auditor-General will undertake sustainable development assurance audits with specific tasks.

Institutional arrangements

Responsibility for water resources development and management is vested in a number of government ministries and statutory authorities, each with its own specific area of interest. There is no national hydrological service with a legal mandate, but a hydrology section within the water supply group of the Public Works Department (PWD) undertakes operational

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[5] Prepared by Mr Rishi Raj, Public Works Department, Fiji

hydrological and water monitoring work. Initially, hydrological investigations were undertaken for the development of water supplies. The data collected over time have been useful for such purposes as irrigation, hydropower development, drainage, bridge design and so forth. The hydrology section has developed over the last two decades, and has the additional responsibility of flood forecasting. The head of the section is the Government's chief advisor on all hydrological matters. The Fiji Meteorological Service (FMS) collects and archives meteorological data from about a dozen synoptic stations for weather services and many more stations for climate information. The PWD hydrology section has collected climate data (wind, temperature, sunshine, radiation and evaporation) from a number of remote locations for its use. These are archived in the FMS climate archive. All of the long term rainfall data from PWD are also archived in the FMS archive.

The Directorate of Water and Sewerage has overall responsibility for the nation’s water supply and is responsible for planning and designing all water supply and sewerage works. The Directorate of Irrigation and Drainage (D&I) within the Ministry of Agriculture is responsible for the planning, design and operations of all irrigation works (as commissioner of irrigation). Other responsibilities are drainage, river training, dredging and land reclamation or sea defense. Limited hydrological data collection and research is undertaken by D&I. As their work is concentrated on the coastal and tidal zone (outside the interest of the PWD), they have some discharge and river level monitoring stations. PWD has provided upstream data from its stations to D&I for such purposes as flood zone mapping and river engineering.

The Department of Energy undertakes development of mini hydropower projects for rural electrification, in close collaboration with PWD's hydrology section. Data, where available, are provided free of charge to the Department. The Fiji Electricity Authority (FEA) operates two hydropower stations. Until recently (1998) PWD provide data collection service on a cost-sharing basis. The FEA has now installed its own real time data capturing equipment, expanding their communication system to remote hydro sites.

Research is only undertaken when there is a crisis (floods, droughts, water shortages). Agricultural research is limited to the irrigation potential of high value crops. The South Pacific Applied Geoscience (SOPAC) training in Earth Science and Marine Geology offers a minor training programme to regional participants.

Although procedures exist to deal with obvious areas of interest common to several organisations, they are at the level of project implementation rather than policy. At present there is no authority that evaluates the priorities of individual user groups, nor any organisation or procedures to cover the less obvious areas. Conflicts have occurred, for example between forestry and water supply, or gravel extraction and water supply.

Relationship between Meteorology and Hydrology

There is a very amicable relationship between the Fiji Meteorological Service and the hydrology section of PWD at all levels. Interaction so far has been largely in the areas of regular data transfers, data requests and specific advice. The FMS has responsibility for weather (including precipitation) forecasting while the PWD is responsible for flood forecasting. Flash floods in January 1999 raised some concerns about forecasting and warning procedures. FMS is willing to provide data collected for Public Weather Forecasts to PWD, but there are operational difficulties. PWD on the other hand does not collect real time data from areas of potential risk of flash floods, nor does it have the personnel and skills to forecast flash floods.

Further development is warranted.

Policies on data transfer and exchange

Hardly any hydrological data are exchanged because PWD is the only organisation that collects hydrological data. Meteorological data archived by the Climate Section of the FMS are made available to users free of charge. A change to the policy of free provision of data and information has been considered. Hydrological data archived by the Hydrology Section of the PWD also are provided to users at no charge, for national stations. The exception has been the FEA, which requires data from remote locations and not from the national network. They contribute towards the cost of construction, operation and maintenance of specific stations. International data exchange is virtually non-existent for operational purposes, but may be useful for drought index development in future.

Fiji contributed to the Global Runoff Data Centre from one undisturbed catchment until the construction of a large hydro dam. Data for research are provided without restriction to universities, post graduate students and research organisations. PWD staff feel that consulting firms receive considerable financial gain from their data, without having any financial input. Value added products such as providing probabilities of flood levels to insurance companies, for example, bring significant financial gains to consultants. Some charges would be useful for developing the services beyond current level of operations.

Assessment

Water resources assessment and operational hydrology have a low status in Fiji, because other demands are more pressing and political pressure is to address the immediate needs of the country for water supply reticulation, roads, education and health. Resources are limited, and social needs take on higher priority. However, recent frequent floods and water shortages are directing more attention to water issues.

The Sustainable Development Bill when enacted will provide the impetus needed for the development of better networks, vigilant monitoring, and research, through institutional development, training and funding.

Malaysia[6]

Background

Malaysia has a land area of 330,000 km^2, in the eleven states of Peninsula Malaysia, Sabah and Sarawak. The country lies within the humid tropics, and its climate is equatorial and greatly influenced by both the north-east and the south-west monsoons. The monsoons typically bring heavy rainfall, and convectional rain is common during the inter-monsoonal periods. The average annual rainfall amounts to some 3,000 mm, but there is considerable spatial variation, with the highest rainfall exceeding 5,000 mm and the lowest at about 1,750 mm. Malaysia is rich in water resources, receiving an annual average of 990 billion m^3. Of this, 360 billion m^3, (36 %) returns to the atmosphere as evapo-transpiration, 566 billion m^3 (57 %) appears as surface runoff, and the remaining 64 billion m^3 (7 %) goes to recharge groundwater.

Water demand is growing at a rate of 4 % annually, and is projected to be about 20 billion m^3 by 2020. This is less than 4 % of annual runoff, but due to the variations in rainfall, some regions of high water demand are approaching the limits of readily available water. Water stress has become more prevalent over the past few years, culminating in a water crisis affecting some parts of the country in early 1998. The current population now exceeds 20 million, and rapid urbanisation and industrialisation over the past two decades have brought deterioration of river water quality – a serious matter, since 97 % of water use originates from the rivers. At the same time, the high rainfall during the monsoonal periods results in large areas being subjected to flooding. An estimated total of about 29,000 km^2 (9 % of the total land area of the country) is flood prone, affecting some 15 % of the population. The average annual flood damage was estimated at RM 100 million (at 1980 prices) but this has increased as a result of urban expansion and the escalation of land and property values.

The legal basis of hydrology and water resources management

Under the Federal constitution, water and land resources are basically state matters; the Water Act (1920) provides that “the entire property in and control of all rivers in any State is and shall be vested solely in the Ruler of such State.” Other matters on the “state list” include water supply and riverine fisheries, while hydropower and navigation are on the “federal list”, and irrigation and drainage are on the “concurrent list”. There is no comprehensive water or river law, and the 40-odd different federal laws related to water – many of which are old and obsolete – are predominantly sectoral, and are administered by numerous federal, state, and local government agencies.

Institutional arrangements

There are many ministries, departments and agencies with functions related to river management. For instance, the Public Works Department is responsible for domestic and industrial water supply, the Department of Irrigation and Drainage for irrigation, drainage and flood mitigation, the Department of Environment for pollution control, and the Ministry of Health for sanitation. No single agency is entrusted with managing water resources in an integrated manner, and the numerous agencies tend to carry out their legally defined, sectoral functions in a somewhat fragmented and independent fashion. Mechanisms for enabling linkages are weak, the principal exceptions are the National Water Resources

[6] The material for this case study was drawn largely from Keynote Addresses given by the Director-General of the Department of Irrigation and Drainage, to the *International Conference on Hydrology and Water Resources of the Humid Tropics*, Ipoh, November 1998, and the *National Conference on Rivers 99*, USM, Penang, October 1999. The assistance of Azmi bin Md. Jafri (Jabatan Pengairan dan Saliran Malaysia) is gratefully acknowledged.

Council, which has national policy and planning functions, and the recently established Selangor Water Management Authority, which will have responsibility for all aspects of water resources management, planning and regulation in the state of Selangor.

The principal hydrological agency in Malaysia is the Hydrology Division of the Department of Irrigation and Drainage (DID). The Division is responsible for the collection, collation, processing, analysing and dissemination to end-users of hydrological data and information. It carries out water resources assessment, develops provides hydrological flood forecasting and warning services for the major river basins, carries out studies to establish standards and guidelines for hydrological practices, and is engaged in hydrological research and development (Figure 1). The Division operates at both State and Federal levels, with data acquisition, pre-processing, and archiving (in Sabah and Sarawak) by State personnel, and data archiving, R&D, and various support activities carried out at the Federal level.

There are 26 member agencies of the National Committee for the IHP. A number of them are involved in hydrological data collection, including (Table 1):

- the Malaysian Meteorological Service (MMS) which started recording rainfall data at all airports some 50 years back, and which has responsibility for weather forecasting, hydrometeorology and climate studies.
- the Water Supply Division of the Public Works Department (PWD), which collects data for water supply projects
- the National Electricity Company - Tenaga Nasional Berhad (TNB) – with a network to collect hydrological data for hydropower projects
- the Department of Environment (DOE) and the Ministry of Health (MOH) with extensive networks of river water quality sampling stations
- the Geological Survey Department (GSD), which monitors groundwater
- other organisations, including a number of large agricultural plantations which maintain their own rainfall stations.

The need to redesign the hydrological network to address evolving needs, such as the growing importance of environmental considerations, is recognised. It is intended to integrate some of the individual agencies' networks into a truly national network.

The DID uses standard types of equipment for hydrological data collection to ensure uniformity of data. Techniques of data collection are in accordance with the standards specified in "Technical Regulation - Hydrology and International Codes" published by WMO in 1980. There has been rapid progress over the last decade in introducing new technology to hydrological practice. These include, *inter alia,* new sensors and dataloggers, radio, telephone and satellite telemetry, and an enhanced data processing and archiving system – the Malaysian Hydrological Information System – and new approaches to drought monitoring and forecasting. There is a strong emphasis on quality management, with the Instrumentation Unit receiving ISO 9002 certification in 1996, and an intention of achieving similar certification for the State Hydrology Units and the Federal Database Unit by the turn of the century.

Table 1 - Sources of Hydrological Information in Malaysia

Types of information	Operating Agency					Total	Purpose
	DID	MMS	DOE	MOH	Other * Agencies		

Rainfall	1038	271	-	-	49	1358	i) DID – basic water resources planning, development and management, flood monitoring and warning ii) MMS – long term observation for climatic change and weather prediction
Evaporation	55	60	-	-	-	115	-ditto-
River stage and discharge	195	-	-	-	24	219	i) DID - basic water resources planning, development and management, irrigation, monitoring and warning for drought and flood. ii) Other agencies- hydropower generation and water supply requirements
River suspended sediment	108	-	-	-	-	108	Estimation of river suspended sediment yields for water resources projects.
Ground-water	-	-	-	-	115	115	Baseline data collection and groundwater quality monitoring.
River water quality	70	-	800	458	-	1328	i) DID- base line data collection ii) DOE- river water quality classification, monitoring and enforcement iii) MOH - river water quality monitoring at water supply intake points

* Note: Other agencies:
- i) Rainfall - Federal Land Development Agency (FELDA), PWD, Dept. of Agriculture (DOA), TNB and Agricultural Plantations
- ii) River stage and discharge – TNB and PWD
- iii) Groundwater - GSD Peninsular Malaysia

Relationship between meteorology and hydrology

As MMS operates and maintains a fairly large network of rainfall and evaporation stations, a joint DID-MMS task force was recently formed with the objective of standardising instrumentation within MMS and DID. Similar efforts are underway to look into the possibility of standardising groundwater and river water quality sampling methods, which involve the GSD, DOE, PWD, MOH and DID. Apart from standardising the measurement parameters, the task forces, which are sub-committees of the National Committee for the IHP, are looking into greater co-operation among the various agencies to enhance hydrological data collection, with the ultimate objective of facilitating information sharing.

Policies on data transfer and exchange

Hydrological data have been disseminated to users in many different forms. In the early years, such information, in book form, covered 2-5 year periods. Beginning in 1974, a series of 20 Water Resources Publications (WRP) was published, providing *inter alia*, information on the water resources of the country. With computerisation, it is no longer necessary to published hydrological information in books. Now, requests for more detailed hydrological data for specific purposes, as computer printouts or data saved onto diskettes, can be easily met. There are also plans to disseminate hydrological data to users on CD-ROMs. To meet growing demands for information, a hydrological data and information management and dissemination system, the Malaysian Hydrological Information System (MHIS), has been developed It has the primary goal of enhancing the planning, development and management of water resources in Malaysia.

A nominal charge is levied on the supply of hydrological data to the private sector, to cover the cost incurred, while data conveyed to government agencies and institutions of higher learning are not charged for.

Malaysia is strongly committed to involvement in international hydrological activities. It participates in international programmes that require data exchange, including in particular the Asia Pacific FRIEND project of the UNESCO International Hydrological Programme. It has established the Regional Humid Tropics Hydrology and Water Resources Centre for Southeast Asia and the Pacific, one of whose key roles is to act as a regional hydrological data centre.

Assessment

Despite fragmented legal and institutional arrangements for water resources management, Malaysia effectively has a National Hydrological Service, the Hydrology Division of the Department of Irrigation and Drainage (DID). Reflecting Malaysia's federal system of government, the Division carries out data collection at state level, and archiving, analysis and dissemination principally at federal level. Hydrology in Malaysia is over 120 years old, and has played a significant and recognised role in national socio-economic development. The Hydrology Division and its parent organisation are well resourced, and have been able to establish a very effective, needs-focussed hydrological programme. Extensive introduction of modern technology and, in particular, adoption of world-class quality management processes are noteworthy aspects of the operation.

There has been a gradual redefining of the roles of government and the private sector in Malaysia, and a growing demand for more transparency and accountability in government-provided services. In the future, it is expected that hydrological data and information will have to be provided at competitive prices, with little or no financial input from government. The onus will be on the DID to maximise operating efficiencies while maintaining the required quality. There will be a need to maintain a national network in spite of anticipated reduction in operating budgets, and to recover the actual cost of data acquisition. It is expected that there will be a reduction in the demand for traditional hydrological data and information, but new demands for valued-added information, by users willing to pay. The organisational environment will be one of greater flexibility and independence, leading towards corporatisation or privatisation of the hydrology service in the future.

New Zealand[7]

Background

New Zealand's three main islands have a total land area of 268,000 km2, and lie in the temperate latitudes of the southern hemisphere. The population of 3.8 million is 85% urban, but the nation is still heavily dependent on agriculture, forestry and tourism for its income. The country's total water resources, estimated at approximately 300,000 million m3/y (mcm/y), are ample for human needs, since water consumption is only around 2,000 mcm/y. Comsumption includes irrigation (1,100 mcm/y), livestock (350 mcm/y), domestic (210 mcm/y) and industry (260 mcm/y), and usage by hydro-electricity stations exceeds 100,000 mcm/y. However, because of the very uneven distribution in time and space, periodic droughts and floods are a significant feature of life in most places. Careful management of the resource increasingly is essential, to deal with growing competition for water, and to mitigate the effects of flood damage and drought.

Environmental and water resource administration has undergone comprehensive change during the last 15 years, in response to the aim of successive governments to achieve:

- Clear separation of administrative functions: policy development, regulation, public service delivery, commercial operations.
- Streamlining of legislation.
- Devolution of many governmental functions to the most local possible level.
- Reduction of central government expenditure and taxation levels, and a shift from a “command and control” economy to one based as far as possible on free enterprise.

A review of water resources assessment capability in New Zealand was carried out in 1990, using the WMO-UNESCO methodology. Major changes in water resources management have changed the picture markedly since then, although the national capability is adequate – within the limits of finite financial resources – to meet the nation's needs.

The legal basis of hydrology and water resources management

Water resources management is carried out principally under the Resource Management Act 1991, with some functions mandated by the much older Soil Conservation and Rivers Control Act 1941. The RM Act provides for gathering the environmental information, including the collection and provision of hydrological data, required for environmental and resource management. This act addresses the powers and functions of regional and district councils, as well as the Minister of the Environment (and, implicitly, the Ministry for the Environment, which provides policy advice and support to the Minister, but has no operational responsibilities). The regional councils operate principally under the Local Government Act and its various amendments. A key requirement is for them to operate in a business-like manner, including development of annual plans, strict financial management, wide consultation with stakeholders, and effective performance reporting.

To the extent that other organisations, such as the state-owned Crown Research Institutes or electricity corporations, are involved in hydrological research and data collection, their water-related capabilities are implicit in the legislation that established them. Much water-related infrastructure such as community irrigation schemes was developed by the State, but it has all been sold to the private sector, or placed in state-owned enterprises that operate on a fully commercial basis. Therefore, no central government departments or ministries in New Zealand have a legal mandate to be involved in operational hydrology or water resources management.

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[7] Prepared by M P Mosley, NIWA, New Zealand

Institutional arrangements

There is no national hydrological service, nor any national government ministry or department with operational responsibility for any aspect of water resources management. The Ministry for the Environment has advisory and policy analysis roles, but water resources are only a part of their responsibilities, and recently have been of lower priority than issues such as genetically modified organisms or waste management.

The eighteen regional councils have primary responsibility for operational water resources management (perhaps, more accurately, regulation) and flood management. They cover the country, and their boundaries are in most places coincident with physical watershed boundaries, to simplify water management. Their legal functions and powers include the data collection necessary to monitor the status of water quantity and quality (at the surface and below ground), and the river environment. These councils all have more or less adequate hydrological observing systems and hydrological expertise – teams of up to fifteen technicians and scientists who collect and manage hydrological data, and analyse them to provide the information and decision-making capabilities required by resource managers.

The Crown Research Institutes (CRIs), particularly the National Institute of Water and Atmospheric Research Ltd (NIWA), the Institute of Geological and Nuclear Sciences Ltd (GNS), and Landcare Research Ltd, conduct a substantial amount of hydrological data collection and water-related research. Their revenues come principally from the Public Good Science Fund (PGSF), which supports innovative research and development that is in the national interest. Data collection as such is not normally funded, but NIWA operates an extensive, nation-wide network of river and lake monitoring stations (originally established by the Ministry of Works and Development) that provide water quantity and quality data for a number of research projects. The administrator of the PGSF has accepted that there is a national need for long-term hydrological information as a basis for trend detection, and provides funding for a network of long-term stations, in addition to the 180 operated for specific research projects. These data are available also for operational purposes. Landcare is principally involved in a number of multiple catchment studies, while GNS focuses on the collection and compilation of groundwater data. Because such data collection is project related, it is vulnerable to termination.

The CRIs also carry out consultancy work for many clients, including national and regional government agencies. A significant part of this involves data collection, notably on behalf of the hydro-electricity and irrigation industry, which requires hydrological records and real time data for operational and legal record purposes. These industries also carry out extensive monitoring themselves, for example of reservoir levels or power station throughflows. Increasingly, recipients of resource consents (often referred to as water rights or permits in other countries) are required to monitor their own impacts on the resource, that is, to monitor water extraction or inflows, and to provide these data on demand to the regional council that issued the consent.

Meteorological data are collected by the Meteorological Service of New Zealand Ltd at nearly 80 automatic weather stations throughout the country. These data are made available to NIWA, as part of the Service's contract with the Minister of Transport, for archiving in the National Climate Archive. The Meteorological Service itself does not have a significant national role with respect to climate data archiving and analysis. NIWA and the regional councils also collect meteorological data, particularly precipitation, at an extensive network of observing stations. These stations often are operated by local residents, some of whom are paid a small fee.

Universities play only a minor role in hydrological research, education, and institutional support, with only a handful of hydrologists on the staff of New Zealand's seven universities. Hydrological education and training is possibly the greatest area of weakness, although no ill effects are apparent.

Relationship between meteorology and hydrology

There are effective functional links between the Meteorological Service – a state owned enterprise required to operate wholly under commercial disciplines – and the regional councils which are responsible for flood forecasting and warning, and water management. Links are both formal, in terms of defined procedures for issuing warnings, and informal, in terms of good personal contacts between the individuals in each agency. The data collected by the Meteorological Service for public weather forecasts automatically are provided via computer links to NIWA, for inclusion on the National Climate Archive.

Policies on data transfer and exchange

New Zealand has been able to maintain relatively unhindered internal exchange of hydrological and meteorological data. Some arrangements, notably between MetService and NIWA or between NIWA and its commercial clients, are contractual in nature. NIWA and most regional councils have agreed freely to exchange hydrological data, and a number of the councils routinely have for many years made data available for placing on the National Water Resources Archive. Distribution of data collected by or on behalf of state-owned enterprises and private sector organisations tends to be more restricted, because the data often are commercially sensitive. However, data often are made available on request for research purposes, subject to conditions on further dissemination.

New Zealand (in practice, NIWA) makes data freely available to international scientific programmes such as FRIEND or the Global Runoff Data Centre, if the requested data in fact are available. No funds explicitly are made available by the government for such activities. Because of the tight accountability and/or commercial nature of the organisations, there is a strong reluctance to process data into specific forms that are requested, unless this readily can be done with the New Zealand data base management system Tideda. NIWA is also reluctant to assemble data (e.g. on extreme events, or metadata on catchment attributes) that are not already routinely collected and archived. Practice is consistent with WMO Resolution 25 (Cg-XIII), although there has been no formal adoption of this resolution by the government. As a remote island country, New Zealand in any case has a limited need to exchange hydrological data with other countries.

Summary and assessment

New Zealand has no national hydrological service. The major national agency with water-related responsibilities, other than the policy development carried out by the Ministry for the Environment, is the National Institute of Water and Atmospheric Research, which is a state-owned research institute. Water resources management and the provision of supporting environmental (including water) information is wholly a function of regional government, whose responsibilities are principally related to environmental matters..

The status of water resources assessment and operational hydrology in New Zealand is satisfactory, within realistic limits set by the size and strength of the economy and the resources available to the regional councils. The clear separation of governmental and other functions, recently revised environmental legislation, pervasive adoption of commercial practices, and high level of devolution to local levels, provide an environment in which water professionals have been able to develop effective systems for information provision. Nevertheless, of course, there are many areas in which better information is always required.

Poland[8]

Background

The Republic of Poland has a total area of 312 685 km^2, and a population of 39 millions, 61% urban. Rivers are the main source of water supply for population, industry and agriculture in Poland, whilst their water resources are among the poorest in Europe. The mean annual runoff is 62.5 km^3 (in the period 1951-1990) or 178.5 mm, that is, approximately 30% of the annual precipitation. The mean specific flow, with an overall average of 5.64 l/(s km^2), is highly variable: from 2.5 l/(s km^2) on lowlands to about 50 l/(s km^2) in Tatra. Spatial and temporal variability of river runoff and hydrological regime in general is caused by the location of the country between the Baltic Sea and the Black Sea, where the influences of the oceanic and continental climates permanently clash. Series of wet and dry years are also the characteristic feature of water resources variability in the long term. Highly heterogeneous hydrogeological conditions in Poland lead to large variations in base flow, and influence the low flow regime. The borders of Poland may be called watersheds, because runoff of Polish rivers is generated on an area only 12% greater than the territory of the country

The legal basis of hydrology and water resources management

In 1919 the Polish State Hydrological Service and the Central Institute of Meteorology were established. The Institute of Meteorology and Water Management was created by act of The Cabinet in 1973, on the base of the State Hydro-Meteorological Institute and the Institute of Water Management. 1999 marks the 80th anniversary of these activities. At the beginning there were only hydrological and meteorological services. Later on some new needs appeared so that the range of services increased.

The Institute of Meteorology and Water Management is a research and development institution under the Ministry of Environment. It is the only governmental agency in the country performing hydrological, meteorological, oceanographic and dam technical control services for protection of the society and national economy, including land, marine and air transport. The Institute manages the warning system for natural disasters (floods, hurricanes, storms, hails, water and air pollution etc.).

Several organisations work in the field of water in Poland. Their activities follow State water policy and water law and concern management of water resources, flood protection and management systems, water engineering, management of rural areas etc. There are also research centres working in the Polish Academy of Sciences, Universities, Technical Schools, Main School of Farming and others. Some of these research centres collect their own hydrological data mostly for mathematical modelling of hydrological processes in small catchments.

Hydrological observations

The need to monitor water level and river flow and for periodic assessment of water resources was recognised very early. The first river gauging stations were established in the 19th century. In the 20th century the hydrologic network has been continuously developed. Nowadays for several gauging stations 100 years' or longer observation series are available. Before the First World War the hydrological network comprised about 500 stations. Two world wars caused damage to the hydrological network and a lot of data were lost. After 1945 the needs relating to the planning, design, operation and management of water projects, including forecasting and control, guided the dynamic development of hydrology and the hydrological network. Due to fulfilled objectives and tasks, the hydrological network in Poland can be divided into four groups of river gauging stations:

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[8] Prepared by Bogdan Ozga-Zielinski, IMWM, Poland

1) operational hydrological network providing real-time data for hydrological forecasting;
2) standard stations providing data to investigations of hydrological regime of the country, planning, design and management (historical data from operational stations are used as well);
3) representative basin network focused on research, of about 40 small catchments with enlarged programme of measurements and observations;
4) special networks for solving specific problems.

The inter-disciplinary nature of water problems and the environmental approach to planning and design led to implementation of the integral State Environmental Monitoring programme in 1991. It is a system of measurements, assessments and forecasts of condition of the environment carried out by the units of central and local administration, as well as universities, institutes and industry. One of the important parts of this programme concerns surface waters - rivers, lakes and the Baltic Sea. Surface water monitoring provides information on water quality based on three types of networks: basic, border and benchmark network. Local Inspectorates of Environmental Protection perform the measurements, IMWM being co-ordinator and supervisor of all activities within the program.

Relationship between meteorology and hydrology

Meteorology and hydrology are the responsibility of a single hydrometeorological agency in Poland.

Policies on data transfer and exchange

As a Member of WMO, Poland follows Resolution 40 regarding data exchange policies for meteorological and related information. Hydrological data are in contrast to meteorological ones because they are much more site-specific. A clearly definable need for the exchange of hydrological data and bilateral co-operation concerns transboundary rivers. When meteorological models are coupled with hydrological models the demand for hydrological data covering large areas increases very rapidly.

There have been various data exchange policies in Poland. from obligatory dissemination of the service’s products, to restricted access during the martial law and several years of economical transformation, and through rigorous commercialisation up to free and unrestricted access at present. Data and products are available for scientific use without charge for the data and standard products themselves. The only restriction is to include the information about the origin of the data in reports or publications. For the provision of countrywide hydrological and base-line information to the public the IMWM publishes periodically summaries of hydrological data for major rivers, presentations and analysis of hydrological events and assessments of water resources.

At the end of 1998 the decision was taken to prepare the essential hydrological and meteorological data on CD-ROMs (the last paper published yearbook was in 1983). This will be a new version of hydrological and meteorological yearbooks available at cost price, accompanied with paper publications presenting summary and characteristic of the year and the data for major rivers, promoting the possibilities and products of the Central Database.

The Central Historical Database was established in Central Office in Warsaw to assure storage of collected data and to provide the information to users and research programmes. The data are stored in two databases: Hydrological Database and Climate Database. The first one contains the daily flows data from about 900 gauging stations, the metadata and catchment monthly precipitation indices as well. Climate Database contains currently:

1) meteorological data (daily and 3-hours values) from 65 meteorological stations starting from 1961 with 10 stations;
2) meteorological data (daily and 8-hours values) from 245 meteorological posts starting from 1951 with 39 posts;
3) daily precipitation data from 1680 precipitation posts starting from 1951 with 333 posts.

Water quality data are stored in Wroclaw Branch Office, which is responsible for maintenance, processing and data analysis.

The groundwater data from 350 stations of a representative network covering the period from 1951 are stored in a groundwater database in Warsaw and processed to assess groundwater level characteristics and runoff. Printing bulletins and internet disseminate the standard products (assessments and forecasts).

There exists a number of databases each focusing on a specific hydrological theme including: small catchments database, oceanographic data centre, long term peak flow data, maximum precipitation data and others.

Summary and assessment

The hydrological service in Poland operates with the financial support of the Government, but for many years had remained under-funded due to the general condition of the country. The last catastrophic flood in 1997 concentrated the attention of polish society and the Government on water and related problems and increasing awareness of the value of information about water can be observed. To adopt the hydrological service to the requirements of a modern world and to improve the system of operational hydrology, the SMOK programme was prepared. SMOK is an acronym for the Hydrological and Meteorological Monitoring, Forecasting and Protection System. With the support of the World Bank the SMOK has just started up. During the next 3 years more then 400 river gauging stations, 500 precipitation stations, 100 groundwater and 60 meteorological stations will be equipped with automatic devices for measurement and transmission of the data (modems, satellite etc.). Modern data and forecasts dissemination system will also be implemented.

Activities under the SMOK programme focus on real-time or near real-time data processing. In the same time two others projects (H-11 and M-11) will be performed in the field of scientific methods of processing, testing, control and analysis of hydrological and climate data. Better retrieval options will continue to be developed making use of advanced GIS technology. Up grading of software for statistical analysis based on historic inputs will occupy a significant part of these projects. The development of guidance material and technical manuals is also planned.

South Africa[9]

Background

The Republic of South Africa, at the southern end of the African continent, has an area of 1,233,000 km^2, and a population of just over 40 million. The climate varies from desert and semi-desert in the west to sub-humid along the eastern coastal areas. Average rainfall is 480 mm/year, and the total average surface water resource is 50,150 million m^3/year. Rainfall is highly seasonal, and also very variable from year to year. Total abstractive water usage in 1996 was 20,350 million m^3/year, over half of it for irrigation and as a result of evapotranspiration by planted forests. Available resources already are fully utilised in many parts of the country, and it is projected that the national resource will be fully utilised by 2030. Sound management of water is recognised as an essential requirement for South Africa's continued social and economic development.

South Africa has undergone significant political and governmental changes in recent years. The water sector has been no exception, with, for example, a renewed emphasis on community water supply and sanitation, as part of the Restoration and Development Programme. The Department of Water Affairs and Forestry – the central government agency with principal responsibility for water resources management – has been restructured, and the Water Services Act (1997) and National Water Act (1998) have placed the management of water resources and water utilities onto a new footing. Internationally, South Africa has been playing an increasing role in southern African affairs; an example of this is its active participation in SADC-HYCOS.

By international standards, South Africa has a good knowledge of its water resources, and an overview of water resources availability and utilisation was published in 1997. The report recognises that major decisions about allocation of scarce resources will be required over coming decades, and several of its recommendations relate to the need to ensure good information and supporting investigations regarding availability and use.

The legal basis of hydrology and water resources management

Water resources management is carried out principally under the National Water Act (1998) and the Water Services Act (1997). The National Water Act establishes the principles under which water resources are managed, for example recognising that all water (surface and underground) is a single, indivisible national asset; introducing the "ecological reserve" and "polluter-pays" concepts; and establishing the aim that water quality is to be maintained in a state that is acceptable to users of the water. Many of these principles have significant implications for the information base that will be required to implement them. Under the Water Services Act, local authorities and district councils are responsible for providing water and sanitation services to communities under their jurisdiction; the associated National Water Supply Regulations require annual water audits, with a particular aim being to minimise unaccounted-for-water. The Water Research Act (1971) provides for the establishment and funding of a Water Research Commission, which commissions research on everything from hydrometeorology and rainfall stimulation through to marine disposal of effluents and municipal wastewater.

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[9] This case study draws heavily on a *Country Report: South Africa*, compiled in 1996 by the World Bank as part of its *Sub Saharan Africa hydrological assessment: SADC countries*. The assistance of Stefan van Biljon (Department of Water Affairs and Forestry) is gratefully acknowledged.

Institutional arrangements

The country report for South Africa, prepared as part of the World Bank's *Sub Saharan Africa hydrological assessment: SADC countries*, provides a valuable, comprehensive overview of institutional arrangements, and their strengths and weaknesses, as they existed in July 1996. In the succeeding three years there have been significant changes, particularly in the responsibilities, structure and management of the Department of Water Affairs and Forestry.

The Department of Water Affairs and Forestry (DWAF) is responsible to its Minister for carrying out most of the functions included within water resources management and operational hydrology. Table 1 shows a simplified organisational hierarchy. The Water Act makes provision for establishment of Water Management Areas, to be managed by Catchment Management Agencies. They are expected to be established over the next 2 or more years; in the interim, regional offices of the DWAF are acting as Catchment Management Agencies.

Within the Water Policy and Resources Branch of the DWAF, the Scientific Services Chief Directorate has five directorates that are responsible for generation of water-related and geographical information; the Hydrology Directorate is regarded essentially as the national hydrological service, although its role relates principally to surface water, and the entire Chief Directorate might better be considered as the service that is providing comprehensive water-related information (including water quality as well as quantity, groundwater as well as surface water). The DWAF collects rainfall data at 374 stations, evaporation at nearly 500 stations, streamflow (including calculated reservoir inflows) at 1,300 sites, and surface and groundwater quality data at several thousand sites. The various databases contain observations from many sites that are now closed; for example, the DWAF surface water database contains records from about 350 closed streamflow stations. Groundwater quality data are very uneven in terms of observation frequencies at the 29,000 bores for which data have been archived, but a National Groundwater Quality Monitoring Programme recently has been established, which includes a core network of 400 stations.

The DWAF operates a matrix management system, and hydrological field teams in the regions are administered within seven regional offices, in the Water Services, Finance and Regions Branch.

The Scientific Services Chief Directorate of DWAF undertakes a wide variety of hydrological, water resources, and flood studies, both for its own purposes and on behalf of other parts of the DWAF. Users of the data and information generated by the Chief Directorate are found throughout the Department, for example in the Water Resources Planning Directorate and Civil Design Directorate of the Development Branch, as well as in other public and private sector organisations. There is a well-developed consulting industry in South Africa, and consultants are major users of DWAF data and products.

The Weather Bureau is by far the most important organisation with respect to the collection and distribution of meteorological data. Its main emphasis is forecasting, but it maintains a meteorological database from which data are supplied free of charge to the public. The Weather Bureau network includes 163 manned weather stations, 116 automatic weather stations, and 2,000 daily raingauges. The Weather Bureau's rainfall data are provided to the DWAF, for addition (annual updating) to its own database.

TABLE 1. Organisation chart: Department of water affairs and forestry

1. **Development Branch**
   - ***1.1 Chief Directorate: Development***
     - 1.1.1 Directorate: Civil Design
     - 1.1.2 Directorate: Mechanical/electrical engineering
     - 1.1.3 Directorate: Consultation
   - ***1.2 Chief Directorate: Planning***
     - 1.2.1 Directorate: Strategic planning
     - 1.2.2 Directorate: Project planning
     - 1.2.3 Directorate: Water resources planning
     - 1.2.4 Directorate: Information services
   - ***1.3 Chief directorate: international projects***
2. **Water services, finance and regions Branch**
   - ***2.1 Chief, Directorate: Regional management***
     - 2.1.1 Directorate: Regional coordination
     - 2.1.2 Directorates: Mpumalanga, Gauteng, Northwest, Free State, Northern Cape, Western Cape regions
   - ***2.2 Chief, Directorate: Northern Province***
     - 2.2.1 Directorate: Operations and maintenance
     - 2.2.2 Directorate: Water resources
     - 2.2.3 Directorate: Development
   - ***2.3 Chief Directorate: Kwazulu/Natal***
     - 2.3.1 Directorate: Water services
     - 2.3.2 Directorate: Water resources management
   - ***2.4 Chief Directorate: Eastern Cape***
     - 2.4.1 Directorates: Water services (West and East)
     - 2.4.2 Directorate: Water resources management
   - ***2.5 Chief Directorate: Finance and administration***
   - ***2.6 Chief Directorate: Water services***
3. **Water policy and resources Branch**
   - ***3.1 Chief Directorate: Scientific services***
     - 3.1.1 Directorate: Institute for Water Quality Studies
     - 3.1.2 Directorate: Geohydrology
     - 3.1.3 Directorate: Hydrology
     - 3.1.4 Directorate: Social and ecological services
     - 3.1.5 Directorate: Geomatics
   - ***3.2 Chief Directorate: Human resources***
   - ***3.3 Chief Directorate: Forestry***
   - ***3.4 Chief Directorate: Water use and conservation***
     - 3.4.1 Directorate: Water conservation
     - 3.4.2 Directorate: Catchment management
     - 3.4.3 Directorate: Water utilisation
     - 3.4.4 Directorate: Water quality management

The Institute for Soil Climate and Water (ISCW), a component of the Agricultural Research Council, operates 350 weather stations, and maintains a climatological data base that contains the Weather Bureau's observations, which are transferred monthly.

The Water Research Commission (WRC) defines water-related research needs in the country, and is the principal source of research funding. It does not itself conduct research and development, but commissions work from universities and consultants. In any one year, there are commonly around 250 research projects under way. The WRC funds the Computing Centre for Water Research, which maintains a hydrological and climatological database and carries research, software development, and other tasks aimed at facilitating the utilisation of water-related data.

A variety of other organisations also collect and compile hydrometeorological, groundwater, and water quality data, in particular the CSIR and university research groups, the Sugar Research Institute, Rand Water and Umgeni Water (bulk water suppliers) and several water boards. In general, these data either add limited value to the data generated at nearby sites by the DWAF, ISCW and Weather Bureau, are captured to those organisations' databases, are collected by the DWAF on contract, or are not readily accessed. Water quality monitoring and groundwater monitoring are particular areas in which organisational difficulties impede an integrated approach to data acquisition and dissemination, because of the involvement of numerous organisations, among whom there is a degree of overlap, omission, lack of cooperation, and sometimes competition.

Relationship between meteorology and hydrology

There are effective functional links between the Weather Bureau and other organisations that require hydrometeorological data. The Bureau makes its data freely available to others for inclusion on their archives, although concerns have been expressed in hydrological circles that the Bureau's rainfall observations do not fully meet hydrological requirements, and that the observation network has been contracting since 1980.

The Hydrology Directorate of the DWAF is responsible for flood warning and management in the Vaal River and Orange River systems. Of utmost importance for this work are the weather forecasts and radar imagery of spatial rainfall which the Weather Bureau supplies to the Directorate. There is a dedicated computer link between the Bureau and the Directorate, to facilitate this collaboration.

The Water Research Commission has funded, and currently is funding, a range of projects that address rainfall estimation and rainfall-runoff issues, such as a project "Short-term weather forecasting techniques dedicated to flood management systems". Both the Weather Bureau and the Hydrology Directorate of the DWAF are represented on project steering committees.

Policies on data transfer and exchange

South Africa in general has recognised the social and economic value of providing ready access to water-related data. Effective computer-based systems for data capture, archiving and dissemination are in place in several agencies, although there are weaknesses in, for example, the ability to combine data from different databases. The Computing Centre for Water Research, funded by the Water Research Commission, is a good example of South Africa's commitment to easy access to water-related data, since only a nominal fee is charged for servicing data requests.

National syntheses have been prepared and published, such as the *Overview of water resources availability and utilisation in South Africa* (1996), a *Sediment yield map of Southern Africa* (1992), and a *National groundwater map* (1995), which is being supplemented with a series of 23 geohydrological maps, giving national coverage at 1:500,000 scale. Again, such activities confirm a policy of making information widely available to users and the public.

Policies on data transfer and dissemination vary, particularly with respect to charging. The Weather Bureau makes its meteorological data readily available to intending users at no charge, and supplies its data to other agencies for addition to their archives. On the other hand, the Institute for Soil Climate and Water has adopted a commercial approach to data dissemination, which has caused some friction with other entities. Its climatological database can be purchased for 20,000 Rand, which includes annual updating; the Institute has not supplied data to the Computing Centre for Water Research since 1992.

The DWAF Hydrological Information System (HIS) is the primary national water data system, containing discharge, water quality, evaporation, rainfall, lake level, and groundwater databases. The Hydrology Directorate of DWAF places considerable emphasis on efficiently supplying data from the HIS, at no charge and in a variety of formats (from hardcopy printouts to direct Internet access) that meet the requirements of their users. Distribution of some data is retricted by privacy considerations, in particular relating to groundwater quality data from private boreholes. Similarly, observations of effluent and receiving water quality, made by effluent dischargers for compliance monitoring purposes and maintained on the DWAF POLMON (POLlution MONitoring) database, are not available to users outside the department. The Hydrology Directorate does not generally provide processed information, such as design flood estimates, to users, in order to avoid legal problems relating to liability.

Rand Water and Umgeni Water report at least annually on the results of their water quality monitoring; reports are available to the public on request, and some of the data are transferred to the DWAF HIS.

South Africa is strongly committed to international cooperation in hydrology, including in the area of data exchange. Notably, it is playing a significant role in the SADC-HYCOS, including making available the data captured by its existing network of DCPs, and providing the services of the regional centre.

Assessment

In South Africa, there are numerous organisations and entities collecting various types of water-related data. The principal hydrometric agency in the country is the Scientific Services Chief Directorate of the Department of Water Affairs and Forestry, whose Hydrology Directorate is designated the national hydrological service.

The major data collection programmes, operated by the Weather Bureau and the Department of Water Affairs and Forestry, provide computer databases whose contents are made available to users on a generally unrestricted basis. Climatological and surface water data are readily available, and the DWAF Hydrological Information System provides a core resource for surface water, hydrometeorological, groundwater, and water quality data management and dissemination. The *Country report for South Africa*, compiled by the World Bank, does emphasise, however, that maintenance of the data and information management programmes into the future is very dependent on skilled people, particularly in information technology and other technical areas. It indicates that difficulties in retaining and recruiting staff are putting considerable stress on the ability of the DWAF, in particular, to continue to provide the high standards of service that it has achieved to date.

Water quality and groundwater observation programmes, which are operated for a variety of purposes by many organisations in addition to the DWAF, have not been wholly successful in providing integrated, readily accessed databases, even though the DWAF has national responsibility. The *Country report* analysed hindrances, which appear to stem from historical factors, unclear objectives, and organisational difficulties associated with the number of entities involved.

Significant progress has been made in turning water-related data into information, in the form of national summaries, maps, and the like. A distinctive feature of hydrology in South Africa is the role of the Water Research Commission, which funds universities and consultants to carry out hydrological and water resources research.

Sweden[10]

Background

Sweden, with a land area of 450,000 km^2, has a total water resource of 176 km^3/year, and withdrawals (1990 figures) of only 4 km^3/year. Although the nation's water resource appears abundant in terms of quantity, pressures on water quality – for example as a consequence of acidification due to aerosol deposition – there is a growing need for accurate information on the status of the resource, to support its sustainable management.

The legal basis of hydrology and water resources management

Sweden has a Water Law that regulates construction activities in rivers and alterations of water flow. From 1999, the Water Law will be part of the Environment Act, which addresses all environmental matters. Sweden is working towards fulfilling the demands of the European Water Framework Directive, when it becomes effective.

Institutional arrangements

The Swedish Meteorological and Hydrological Institute (SMHI) acts as the national hydrological agency, under government instruction and an annual budget. It was founded in 1907, initially with its most important role in the area of information for hydropower planning, but with other activities progressively being added. Hydrological and meteorological functions were brought together in 1919, and oceanographic activities were added during the 1970s. The SMHI has just been moved into the Ministry of Environment, from the Ministry of Transport and Communications. Its principal roles are to collect, archive, and analyse meteorological, climatological, hydrological and oceanographic data, generate and distribute public forecasts nd warnings, and provide other value added services, on a commercial basis.

The SMHI operates about 400 gauging stations, 800 precipitation stations, 150 SYNOP stations, and 25 water temperature stations. About 25% of the river flow network is financed by the hydropower industry, and nearly 1/3 of flow stations are monitored using data from power stations or regulating dams. Hydrological observations are carried out by 12 hydrologists/ engineers, who allocate about 7 person/years per year to this task.

The SMHI is structured on market lines, with four business service divisions and a common Internal Operation and Research Division; there is no hydrological division, but hydrologists are found in almost all divisions. The business divisions are:

- Government Service Division, responsible for observations, forecasts and warning, and international activities. Most activities are funded by government grants..
- Transport Services Division, supplying information to aviation, road, rail and shipping companies. All activities are commercial.
- Environment and Energy Services Division, supplying information for power production, environmental investigations, etc. All activities are commercial.
- Media and Business Services Division, delivering weather forecasts to the news media and direct to the public (via fax, telephone answering devices, direct to computers, etc.). All activities are commercial.

10 The assistance of Gunlög Wennerburg (Swedish Meteorological and Hydrological Institute) is gratefully acknowledged.

The Swedish Geological Survey has responsibility for ground water survey, and cooperates with SMHI in producing hydrological forecasts. The Swedish Environmental Protection Board coordinates environmental monitoring, which is carried out by numerous local authorities and commissions. It draws on SMHI information and products, including hydrological analyses for locations at which no data are available.

Water management is divided among a large number of municipalities, which are required, under the Planning and Building Act, to develop a master plan for water use and land use. There are also over 50 inter-municipal river basin entities. In practice, surface water quality and public water supply is emphasised, and the level of information-based planning of water resources appears to be limited in most places – in 1993, only 15 entities had effected a river basin inventory or master plan, and only one had adequate staff resources.

Relationship between meteorology and hydrology

Meteorology and hydrology – as well as oceanography – have been included within SMHI for many decades, and the structure of SMHI's divisions brings these disciplines together in a way that focuses on the requirements of the customers rather than the disciplinary background of the staff. The same telecommunication system, based on the national telephone network, is used for transmitting all types of data, all technical equipment is maintained by a single group of engineers, and the same software is used for all data handling.

Policies on data transfer and exchange

Some of the SMHI's hydrological data are provided by the hydropower industry, and because these may be commercially sensitive, restrictions (for two years) are placed on access for purposes other than forecasts and warnings.

Data are available inside SMHI for forecasts and other purposes. Some data are published monthly, and statistical summaries on longer time scales. Hydrological messages and warnings are issued regularly and as required, under an agreement with the Swedish Rescue Services Agency. All hydrological data are available on request, except for those referred to in the preceding paragraph. As a member of ECOMET, the SMHI grants access to data to external users of data, under the same terms and conditions as the commercial parts of SMHI. The Institute also provides data for education and research purposes, with no charge other than for the direct costs of delivery.

International cooperation in exchanging hydrological data and products is established with the neighbouring countries of Norway and Finland. Sweden is involved in numerous cooperative activities around the Baltic Sea, such as HELCOM and BALTEX. The BALTEX Hydrological Data Centre is maintained at SMHI, and is intended to manage hydrological information from over 200 stations in the region, and disseminate them to researchers. An expert system called HOME (Hydrology, Oceanography, and Meteorology for the Environment) is being developed for application to the Baltic Sea and its catchment, which places a premium on the availability of water quantity and quality data in near-real time, from countries around the Baltic. Sweden is also an active participant in the International Hydrological Programme's FRIEND project.

Assessment

Sweden has a National Meteorological and Hydrological Service, the Swedish Meteorological and Hydrological Institute, which has responsibility also for oceanography, and is located in the Ministry for the Environment. It has been a world leader in introducing a commercial approach to hydrology, oceanography and meteorology. One of the consequences of this has been the introduction of a structure focussed on customer groupings rather than scientific disciplines. Hydrology and meteorology are very closely related, operationally.

Government allocations for hydrology have been progressively reduced, leading to considerable operating efficiencies that depend on highly trained staff, new technology – such as field dataloggers that are downloaded only 2-6 times a year – data collection at controlled sites (where frequent gaugings are therefore not required), and automatic data transmission (where real time data are needed). A significant portion of hydrological data is obtained from the hydropower industry, one of the disadvantages of which is that some of these data cannot be made available for two years because of commercial sensitivity.

Reductions in funding for data collection are requiring the development of improved models for hydrological estimation. This is consistent with the increasingly holistic approach being taken to understanding and managing the Swedish and Baltic environment. Process research is making it possible to develop integrated models of the fluxes of water and other substances through the atmospheric, freshwater, and marine system as a whole. This in turn generates a requirement for input data for the models on a near-real time basis, and also from neighbouring countries.

Tunisia

Environment: planning and management

Because of its location, Tunisia is influenced by two climates, the Mediterranean one in the north and the Saharan in the south, which are responsible for spatial and temporal variability of water resources. Nationwide, average rainfall is 230 mm per year, or 36 billion m^3. In years of extensive drought the figure may fall to 11 billion m^3, and in a very rainy year it may reach 90 billion m^3.

The risks of flood or drought inherent to the country's climate make it necessary to manage surface and ground waters both intra-annually and inter-annually, so as to store the water surplus in wet years and permit it to be used in years of drought.

Since 1970, several water management and planning projects have been drawn up on the basis of an improved understanding of water resources and of trends in water demand in various sectors and regions of the country. Their aims are:

- To draw up a time diagram of works realized;
- To transfer water;
- To protect against floods and develop the use of ground water;
- To improve the quality of treated drinking water in towns and rural areas, and of irrigation water, and to encourage the use of waste water for agricultural purposes.

In 1990 a national mobilization strategy for all identified resources was adopted. Its aim is to meet demand for water in the various sectors over the coming decades.

The administration in charge of water management, which has studied ways of enhancing the results of these plans, has identified several ideas as the main thrust of future water policy in Tunisia. These include:

- Completion of the mobilization of all identified water resources;
- Water conservation;
- Water quality management;
- The use of treated waste water;
- Management of natural disasters (droughts and floods);
- Integrated and rational water use;
- Strengthening of water-management institutions.

Previous plans and studies

The main purpose of the *Economie de l'eau 2000* (Water Conservation 2000) study which was drawn up from 1990 to 1995 under the supervision of the *Direction Générale des Etudes et des Travaux Hydrauliques* (General Directorate for Water Studies and Water Works) of the Ministry of Agriculture was to put forward a water management strategy that would make it possible to meet the nation's water needs both qualitatively and quantitatively for the coming decades.

An *Etude sur la stratégie des ressources naturelles* (Study of natural resources strategy) was carried out in 1997 by the Ministry of Agriculture with the aim of understanding how to provide for the rational and sustainable use of the country's natural resources. The *Etude du secteur de l'eau* (Study of the water sector) is aimed at drawing up responses to questions raised during the preparation of the Ninth Plan and of the *Economie de l'eau 2000* (Water Conservation 2000) study, and at analyzing key problems of water resources management.

Eau 21: stratégie du secteur de l'eau en Tunisie à long terme (Water 21: A long-term strategy for the Tunisian water sector) is a document providing in-depth analysis of how water resources can meet demand, along with the prospects for the water sector in 2010, 2020 and 2030.

The *Guide pratique de gestion de la sécheresse en Tunisie: approche méthodologique* (Practical guide to the management of drought in Tunisia: A methodological approach) is a document prepared with a view to drawing up and detailing a methodological approach to drought management in Tunisia.

Institutional aspects

In Tunisia, all duties related to water are assigned, according to the field in question, to specialized institutions under the responsibility of a number of Government ministries. Since most water resources are used in agriculture, all responsibilities relating to the mobilization and management of water resources have been assigned to the Ministry of Agriculture, which includes several institutions with specific duties. The most important are the following:

- The *Secrétariat d'Etat aux ressources en eau* (State Secretariat for Water Resources), which is responsible for the planning, supervision and monitoring of water development activities;
- The *Direction Générale des Ressources en Eaux* (General Directorate for Water Resources), which is responsible for managing data, research and experiments, for law enforcement and regulations concerning pollution control and the development of ground water;
- The *Direction Générale des Etudes et des Travaux Hydrauliques* (General Directorate for Water Studies and Water Works), which is responsible for carrying out technical studies and the operation and maintenance of dams and other major hydraulic projects;
- The *Direction Générale du Génie Rural et de l'Hydraulique Agricole* (General Directorate for Rural Engineering and Agricultural Water Use), which is responsible for managing drinking water in rural areas and supplying irrigated areas;
- The *Direction de la Conservation des Eaux et des Sols* (Directorate for Water and Soil Conservation);
- The *Société Nationale d'Exploitation et de Distribution des Eaux* (National Water Use and Distribution Company), which is responsible for the use and distribution of drinking water in cities. This is an industrial and commercial public body which covers the entire country, operating under the Ministry of Agriculture. A performance contract concluded between this body and the State sets out the roles of the two parties and specifies the work to be done, the performance expected and the commitments of the State;
- The *Société d'Exploitation des Canaux et Adductions des Eaux du Nord* (Northern Canals and Water Supply Operating Company) is an autonomous public body responsible for a major water supply system in the northern part of Tunisia. It is part of the Ministry of Agriculture and ensures the operation, management, use, maintenance and upkeep of the canal and water supply conduits;
- The various *Commissariats Régionaux au Développement Agricole* (Regional Commissariats for Agricultural Development) and water users' associations, which are responsible for all activities relating specifically to the agricultural sector (distribution, irrigation, use...);
- Research institutes of the Ministry of Agriculture which are responsible for identifying and mobilizing water resources and techniques for purification, desalination and irrigation, as well as for monitoring water quality and identifying economic aspects of water use.

Protecting water resources and defending them against pollution or deteriorating quality are some of the tasks of the Ministry of the Environment and Land Use Planning. The Ministry protects water resources by monitoring discharges and by providing guidance for and encouraging the use of appropriate technologies for the pre-processing of such discharges before they are released into the receiving environment or the urban water treatment network (activities carried out by the *Agence nationale pour la protection de l'environnement*, National Environment Protection Agency, ANPE).

The Ministry is also responsible for the preparation of water treatment and sanitation plans drawn up prior to any discharge into the environment, and for ensuring that water is available for use in agriculture, industry and tourism (this is done by the *Office national de l'assainissement,* National Office of Sanitation, ONAS). Sanitary monitoring of water resources used for drinking water and agriculture is carried out by the services of the Ministry of Public Health, with the aim of eradicating water-borne diseases.

Protection against floods is ensured by the Ministry of Equipment and Habitat through land management plans for towns and basic infrastructure plans for the entire country.

Training, research and technological exchange

The INAT, or *Institut National Agronomique de Tunis* (National Agronomic Institute in Tunis), trains engineers in rural engineering. More specialized training courses are now also being offered by the INAT, which has undertaken major cooperation projects with several other institutions, including:

- ENGREF-Paris (*Ecole Nationale du Génie Rural, des Eaux et Fôrets*, National School of Rural Engineering, Water Resources Management and Forestry);
- ENSEEIH-Toulouse;
- ENSIMA-Grenoble;
- ORSTOM (the French Scientific Research Institute for Development in Cooperation);
- INAP-Grignon;
- ENSA-Rennes.

The ENIT (National Engineering School in Tunis) is responsible for training hydraulic engineers, and works closely with such institutes as:

- ENSEEIH-Toulouse;
- ENSIMA-Grenoble;
- The School of Mines.

The ESIER (*Ecole Supérieure des Ingénieurs et de l'Equipement Rural*, School for Engineering and Rural Equipment) Mejez el Bab offers training similar to that of the Rural Engineering Section of the INAT, with specialization at the following:

- Cemagref;
- Schools in Europe;
- Schools in the United States.

Research institutes under the Ministry of Agriculture work in close collaboration with the Secretariat of State for Scientific Research. Among these institutions are the *Direction générale des ressources en eau* (General Directorate for Water Resources), which carries out research into ground and surface water, the *Institut National de Recherche en Génie Rural, Eaux et Forêts* (National Institute for Rural Engineering and Forestry Research), the *Institut national de recherches scientifiques et techniques de Borj Cedria* (Borj Cedria

National Institute for Scientific and Technical Research) and the *Société nationale d'exploitation et de distribution des eaux* (National Water Use and Distribution Company). These institutions work closely with national universities (ENIT, ENIS, ENIG, INAT, ESIER, Tunis Faculty of Science, etc.) and with universities in various other countries (Morocco, Algeria, Libya, France, United Kingdom, Germany, Russian Federation, Italy), as well as with international institutions (ACSAD, ALESCO, ORSTOM, FAO, WMO, BRGM, GTZ, UNESCO, and ICAMAS).

Tunisia is also involved in the activities of the MED-HYCOS project (the Mediterranean Hydrological Cycle Observing System of WMO and the World Bank), the purpose of which is to keep track of the status and prospects of water resources of the Mediterranean countries by using new technologies and the real-time automatic acquisition of hydrometeorological parameters thanks to the METEOSAT system.

Observation networks

Pluviometric records go back more than a century. The Mannoubia-Tunis station is the oldest, having been established in 1873. The network is currently made up of 808 stations located throughout the country. In addition, Tunisia has a hydrometric observation network which developed mainly in the last three decades; the oldest of these stations dates back to 1898. This network is currently composed of 183 hydrometric measurement stations.

Monitoring of the ground water in Tunisia is currently carried out by 3,015 monitoring devices located at 2,209 surface wells, 712 piezometres and 94 drilled sites. The network for monitoring the quality of ground water consists of 874 observation points, including 578 surface wells and 296 drilled wells.

All these pluviometric, hydrologic and hydrogeologic data have made it possible to take stock of the country's water resources, providing precious information for local, regional and national water resource planning. This information is stored in computerized databanks at the Ministry of Agriculture (General Directorate for Water Resources) and, in the case of pluviometric data, at the National Meteorology Institute.

Summary

Tunisia is a country with relatively limited renewable water resources. Indeed, there are only 4,700 million m^3 of resources, of which 550 million m^3 are non-renewable. Consequently, the ratio is just 450 m^3 of renewable water per person per year, which is considered low. According to international standards, countries with annual resources of less than 1,000 m^3 of water per capita are deemed to be lacking water resources.

Despite this, Tunisia has been able to meet the water needs of the various sectors even in times of relatively serious drought. The percentage of the population provided with clean tap water has reached 100 per cent in towns and 71 per cent in rural areas, with no rationing even during shortages. Irrigated agriculture has developed over some 335,000 ha, or 7 per cent of the arable land, and now accounts for an average of 32 per cent of the overall value of agricultural production.

TRENDS IN CERTAIN INDICES IN TUNISIA IN 1996 AND 2030

Index	1996	2030
Population of Tunisia (thousands), with growth at 1 per cent	9,170	13,000
Gross National Product (GNP in millions of dinars)	18,200	379,000
Renewable resources in millions of m^3 per year	4,670	4,670
Volume tapped, in million m^3 per year	3,100	3,800
Volume usable, in million m^3 per year	2,647	2,732
Overall demand for water (million m^3)	2,500	2,800
Demand for irrigation water (million m^3)	2,100	2,000
Area irrigated (thousand hectares)	335	470
Demand for drinking water (million m^3)	290	490
Demand for industrial water (million m^3)	100	200
Demand for water for the tourist industry (million m^3)	20	40
Per capita GNP (dinars per capita)	2000	29000
Volume of water available per capita, per year (m^3/person/year)	450	315
Demand for water per hectare (m^3 per ha)	6,300	4,300
Demand for water per capita, per year, in m^3	273	215
Demand for drinking water in litres per capita, per day	87	103

Uruguay[11]

Introduction

The Eastern Republic of Uruguay has a land area of 176,215 km^2 and is located in a temperate zone, between 30° and 35° south latitude and 53° and 58° west longitude.

Mean annual temperature is 18° C, with the following means for each season: 17.5° C in spring; 25° C in summer; 18° C in autumn and 12° C in winter. Annual precipitation is on average 1,100 mm, and the country's relief is low, with a mean elevation of 117 m above sea level and a maximum of 514 m. The population of 3.2 million is 95 per cent literate; 50 per cent live in the capital and 50 per cent in the rest of the country. Nonetheless, the country is still very dependent on agriculture, livestock and tourism. Production is currently becoming more diverse, with the rice, forestry, wine and fisheries industries growing quickly.

Uruguay's territory is divided into six shallow catchment areas, as follows: (1) the Uruguay River basin (26 per cent, or 45,571 km^2); (2) the Río de la Plata basin (7 per cent, or 12,188 km^2); (3) the Atlantic Ocean (5 per cent, or 8,468 km^2); the Mirim Lagoon basin (16 per cent, or 28,747 km^2); the Negro River basin (39 per cent, or 67,947 km^2); and (6) the Santa Lucía River basin (8 per cent, or 13,294 km^2). The Uruguay River basin and the Negro River basin, representing some 65 per cent of the national territory, are part of the Lower Uruguay River basin, which has an overall area of nearly 384,000 km^2 and straddles Argentina, Brazil and Uruguay.

The country's water resources are estimated at about 70,000 million m^3 per year, not counting groundwater reserves and inflow from the upper Uruguay River basin. Water consumption is 1,778 million m^3 per year, and can be broken down as follows: irrigation (1,693 million m^3 per year); domestic use (75 million m^3 per year); industrial uses (8 million m^3 per year) and other uses (2 million m^3 per year). Water use for hydroelectric power is 44,000 million m^3 per year in the Negro River basin (Gabriel Terra, 11,000 million m^3 per year; Baygorria, 14,000 million m^3 per year; and Palmar, 19,000 million m^3 per year) and 150,000 million m^3 per year at the Salto Grande dam on the Uruguay River.

While there is no shortage of water resources, they are not evenly distributed in time or space. As a result, various parts of the country experience serious flooding and droughts.

Legal aspects of hydrology and water resources management

At the national level, the Water Code (Act 14.850 of 15 December 1978) is the law that governs water rights and sets out the competencies and responsibilities for the evaluation and management of the country's water resources by the *Dirección Nacional de Hidrografía*, or DNH (National Directorate for Hydrography).

As the DNH has developed and gained experience since its inception, various legal standards have been adopted which have changed and adapted this body to help meet the needs of society, and in particular the needs of water resource users.

The most noteworthy changes and regulations are:

- The Act of 10 November 1987, which modified the fines applicable to persons who alter water quality without authorization;

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[11] Prepared by A. Arcelus, *Dirección Nacional de Hidrografía* (National Directorate for Hydrography), Montevideo.

- Decree 253/79 of 9 May 1979 concerning standards for water pollution monitoring, and Decree 579/89 of 11 November 1989, which amended the previous Decree by establishing new limits for certain parameters;
- Decree 160/980 of 19 March 1980, governing the use of power generation runoff for irrigation and various other purposes;
- Act 16.170 of 28 December 1990, which placed under the responsibility of the Ministry of Housing, Regional Planning and Environment the protection of water against noxious effects, including those which could alter the ecological balance of fauna and flora and damage the environment;
- Act 15.239 of September 1981 on "Agricultural Land and Surface Water Use and Conservation";
- Act 16.320 of 1 November 1992, which sets fines for violations of article 4 of the Water Code;
- Act 16.858, "Agricultural Irrigation in the Public Interest";
- Decree 435/995 of 29 November 1995 on the use of rain water.

The Water Code also establishes, in article 3, that the Executive Branch is the national authority for water management, and that as such it must "draw up national water policies and implement them in appropriate programmes or projects which are integrated in the general management of the country, regions and sectors ". This notwithstanding, no formal document has been drawn up explicitly setting out water policy.

Nonetheless, the Water Code itself provides general outlines which may be considered to be part of a national water policy, such as the declaration in article 2 to the effect that "the State shall promote the study, conservation, and the full and simultaneous or subsequent use of water resources, and shall take action against the harmful effects of such resources". Similarly, article 3 indicates that the Executive Branch shall "establish priorities for water use by regions, basins or parts thereof, assigning the highest priority to the provision of drinking water for the population". This at least sets an order of priority for resolving potential conflicts.

Institutional provisions

National and binational bodies with various mandates for the evaluation, management and administration of water resources include the following:

- The *Dirección Nacional de Hidrografía* (National Directorate for Hydrography) (DNH) of the Ministry of Transport and Public Works (MTOP), through the Water Resources Division, is responsible inter alia for the operation of the national hydrological network, the operation and updating of the National Inventory of Hydrological Data and the maintenance of the country's navigable waterways. The National Hydrometric Network has approximately 140 operational stations which carry out daily measurements of water levels. The DNH also issues permits, concessions and authorizations for the use of water and waterways in the public domain. Through regional projects implemented in accordance with national programmes, it ensures the protection of people and property against floods;
- The *Dirección Nacional de Meteorología* (National Directorate of Meteorology) (DNM) of the Ministry of Defence, in addition to normal activities in the field of meteorology, carries out the observation, processing and dissemination though its Climatology and Documentation Division of all hydrometeorological information produced in the country;
- The *Dirección Nacional del Medio Ambiente* (National Directorate for the Environment) (DINAMA) of the Ministry of Housing, Regional Planning and Environment (MVOTMA) has since 1990 evaluated and monitored water quality in the country's main waterways, industrial dumping (issuing authorizations for industrial

discharge) and beaches. It has also been responsible for approving the environmental impact evaluation studies which are required by law. Decree 253 of 1979 establishes standard regulations for the control of water with a view to preventing environmental pollution and defines classification criteria for receiving water bodies (article 3), as well as water quality parameters (article 5) and emission parameters for effluents (article 11). Under the Decree, the MVOTMA is responsible for the classification of water bodies in Uruguay;

- The *Administración de Usinas y Transmisiones Eléctricas* (Electical Transmission and Plants Administration) (UTE), through its *Departamento de Presas y Embalses* (Dams and Reservoirs Department), carries out hydrological activities for the operation of hydroelectric systems in the Negro River basin;
- The *Administración de Obras Sanitarias del Estado* (State Sanitation Works Administration) (OSE) is the administrative body responsible for providing drinking water to all populated areas and for sanitation services required outside of the Department of Montevideo. It also systematically measures water quality at various sources, and measures the quality of water effluents;
- The *Dirección Nacional de Minería y Geología* (National Directorate of Mining and Geology) (DINAMIGE) of the Ministry of Industry, Energy and Mining finds groundwater, measures the volume of extracted groundwater and determines its quality;
- The *Dirección de Uso y Manejo del Agua* (Directorate for Water Use and Management) (DUMA) of the Ministry of Livestock, Agriculture and Fishing (MGAP) monitors the water quality at the various sources used for irrigation;
- The *Servicio de Oceanogragía, Hidrografía y Meteorología de la Armada* (Naval Oceanographic, Hydrographic and Meteorological Service) (SOHMA), through its Oceanography Department, operates inter alia tide gauges in the country's main ports;
- The *Comisión Técnica Mixta de Salto Grande* (Joint Technical Commission for Salto Grande) (CTM) is a joint Argentine-Uruguayan institution which evaluates water resources and makes forecasts to support hydroelectric power generation in the Uruguay River basin;
- The *Comisión Administrativa del Río Uruguay* (Commission for the Management of the Uruguay River) (CARU) is a joint Argentine-Uruguayan institution which, with the support of some of the bodies mentioned above, carries out activities for the evaluation of water resources related to navigation and water quality in the Uruguay River. This Commission was established under the Statute of the Uruguay River, which was signed by the two countries in February 1975 and was largely based upon the Treaty on the Limits of the Uruguay River of 7 April 1961. The CARU's budget is drawn from the national treasury and from its own resources. The CARU currently has agreements and conventions with the competent bodies of both countries, which provide it with technical and professional staff.
- The *Comisión Administrativa del Río de la Plata* (Río de la Plata Administrative Commission) (CARP) is another binational institution with a structure and composition similar to those of the CARU, but which covers the Río de la Plata.

Institutional coordination

In Uruguay there is no formal, permanent coordination mechanism or instrument for all the bodies which evaluate and manage water resources. However, there are specific agreements between some bodies. For example, the Ministry of Livestock, Agriculture and Fishing and the Ministry of Transport and Public Works cooperate in Irrigation Boards, which issue irrigation authorizations. Another example is the technical cooperation agreement concluded in 1995 between the Ministry of Housing, Regional Planning and Environment and the Ministry of Transport and Public Works, which mentions the possibility that the two bodies will work together to exchange information and expertise with a view to drawing up and carrying out works, services, programmes and technical cooperation and specialized projects. Similarly, the *Administración de Obras Sanitarias del Estado* (State Sanitation Works Administration) and the Ministry of Transport and Public Works share information and govern rights related to direct access to irrigation channels and to the tapping of other water sources.

Uruguay also has a national emergency system. Its main purposes are to plan, coordinate, implement, conduct and evaluate activities required in all exceptional emergency, crisis or disaster situations which might take place in the national territory. This system, which can be invoked by the Office of the President of the Republic, operates only in specific situations, when a crisis cannot be resolved by the competent bodies working within their regular mandates.

Two bodies play certain coordinating roles in the field of hydrology:

- The *Comité Nacional para el Programa Hidrológico Internacional del UNESCO* (National Committee for the UNESCO International Hydrological Programme) (CONAPHI) was established in 1976 and is composed of representatives of various institutions related to hydrology. So far, it has held over 68 meetings and has played an active role in various international programmes coordinated by UNESCO;
- The WMO HOMS (Hydrological Operational Multipurpose System) National Reference Centre was set up in 1982 and includes representatives of various bodies, who periodically hold coordination and promotion meetings. Generally, the meetings are held jointly with those of the CONAPHI.

Data transfer

A National Clearing House of Geographical Data is currently being set up in Uruguay, with the participation of the institutions mentioned above. Users (public and private) can find out what information is available, learn where to find it and, if they so desire, obtain it through the Clearing House.

Certain bodies have published annual reports on their activities. The DNH and DNM provide data to the private and public sectors upon request. The DNH also exchanges data with the Intergovernmental Coordinating Committee on the Río de la Plata Basin.

Evaluation

In Uruguay, some 2.5 per cent of the potentially available water resources are used, which means this resource is not considered scarce. However, water is not evenly distributed in time and space. Various parts of the country experience serious flooding and droughts.

Some 97.9 per cent of resources tapped directly from rivers and streams are used in agriculture; 0.7 per cent is employed in industry and 1.4 per cent is provided to the population. A supply and demand analysis of these intakes was carried out in the summer, and indicated that 59 per cent of the flow which can be authorized nationally by the DNH is currently being consumed. For this reason, in recent years storage capacity has increased, with the maximum irrigation volume of dams and other structures reaching about 1,400 million m^3.

In order to ensure that the available water resources are used in an organized and sustainable manner and to mitigate the effects of floods and droughts, it will be necessary to plan resource management activities. The best possible way to ensure sustained growth is by having a consistent water policy with continuous implementation. For this reason, the DNH is preparing national studies for the planning and use of the water resources of most of the basins in the country.

ANNEX 2

INTEGRATED WATER RESOURCES MANAGEMENT

Summary[12]

There is a huge amount of literature which reports on and analyses international experience in what is generally called Integrated Water Resources Management (IWRM). Integrated management is usually considered at several levels:

- The different components of the hydrological cycle – groundwater, surface water, quantity and quality etc.
- the many socio-economic demands placed on water – irrigation, hydropower, etc.
- the several components of the aquatic/catchment system – vegetation cover, soils and erosion, land use, water quality, instream ecosystems, etc
- the institutions and laws/policies in place for resource management – civil, environmental, agricultural, infrastructure agencies, etc
- the geographical entities involved – in particular, the catchment as the "fundamental unit" of management, and its relationship to the boundaries of civil and other administrations.

IWRM is considered to include not just water, but the land, soil, rock, chemicals (of natural and human origin), dependent biota, and human institutions and activities associated with water and its use and management. Water is regarded as the "unifying element", because it is the transporting medium for particulate and dissolved matter and an essential requirement for all life, aquatic and terrestrial. Notwithstanding other natural processes and cycles, the hydrological cycle – and its physical expression, the river catchment and groundwater aquifer – is acknowledged world-wide to provide an effective basis for IWRM.

There is a strong, international consensus that a "river basin approach" provides the most effective and efficient means of developing and sustainably managing land, water, and associated biological resources. I am aware of no international conference or organisation that has ever recommended against adoption of a "river basin approach". There is a world-wide trend towards the adoption of such an approach. This is generally associated with the establishment of institutions whose boundaries are coincident with river basins, commonly as agencies which are additional to those responsible for civil administration, in countries where sub-national government boundaries do not coincide with river basins.

For historical reasons, there are many river basins in which land, water, and associated environmental resources are <u>not</u> managed using a "river basin approach". The costs are recognised to include a failure to achieve the desired outcomes (eg, inefficient or inequitable allocation of water to environmental and other uses), conflict among the people and administrations involved (leading in extreme cases to armed conflict), and/or the cost of establishing administrative, coordinating, and conflict-resolution mechanisms.

SUMMARY OF INTERNATIONAL EXPERIENCE ON CATCHMENT MANAGEMENT

United Nations General Assembly

The Nineteenth Special Session of the UNGA (June 1997) adopted a *Programme for the further implementation of Agenda 21*. In its treatment of environmental sectors, the programme placed freshwater first, indicating the importance attached to freshwater: *Water resources are essential for satisfying basic human needs, health and food production, and the preservation of ecosystems, as well as for economic and social development in general. (para. 34).*

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12 This document originally was prepared by M P Mosley as evidence to a judicial hearing on local government boundaries in New Zealand.

To address the issues, the programme recommended eight actions. The first (and by usual convention the most important) was to (para. 34):

Assign high priority, in accordance with specific national needs and conditions, to the formulation and implementation of policies and programmes for integrated watershed management, including issues related to pollution and waste, the interrelationship between water and land, including mountains, forests, upstream and downstream users, estuarine environments, biodiversity and the preservation of aquatic ecosystems, wetlands, climate and land degradation and desertification, recognising that subnational, national and regional approaches to freshwater protection and consumption following a watershed basin or river basin approach offer a useful model for the protection of freshwater supplies.

The recommended action implies that (i) integrated watershed management is deemed to include the full range of environmental issues (not including air); and (ii) the river basin approach is considered to be the preferred management model, since no others are cited.

The Report on *Strategic approaches to freshwater management* of the UN Secretary General to the 6th Session of the UN Commission on Sustainable Development (April 1998) affirmed (para. 40) that *the explicit incorporation of freshwater management in overall environmental policy is critical to maintain the stock of environmental assets and associated economic and environmental services*. The Secretary General recommended three sets of interventions to do this. The first set is titled *Integrating land and water resources management*. It includes four specific actions, which include (para. 41):

Promotion of integrated land and water management within the framework of national development plans, and study of the linkages between regional economic development programmes and integrated river basin management;

Development of river basin action plans, especially for high priority risk basins, including their rivers, lakes and aquifers, to integrate land-use planning, especially in upstream regions, with water management and conservation; coordinate the activities of provincial, national and international agencies, and address transboundary issues;

Some of the wording reflects the international scope of the report, but the report clearly advocates integration of environmental management and economic development, and that the river basin is an appropriate entity for this.

World Bank

The World Bank invests heavily in water-related developments, and has a strong interest in achieving sustainable water management. In a recent (1995) essay *Towards sustainable management of water resources*, the Bank's Vice-President Serageldin identified four principal failures in water management. He expressed the first as follows:

Water management is fragmented among sectors and institutions, with little regard for conflicts or complementaries among social, economic, and environmental objectives. There are multiple agencies for different uses – for example, irrigation, municipal water supply, power, and transportation – and inter-sectoral interactions within an interdependent system are usually ignored. … In many countries where individual states or provinces have jurisdiction over water in their territory, the same water source will be developed without considering the impact on other states. Similarly, domestic, industrial and commercial supplies often are provided by local governments that are not coordinated with provincial or national water agencies. The result often is excessive and unproductive investments, with different agencies developing the same water source for different uses.

There are many rivers in which fragmented water management (his term) has been harmful to the water resource and to the interests of water users – Serageldin cited the Chittar and Cauvery Rivers of India. Extreme cases (cited by other World Bank reports) include the Indus, Euphrates, Ganges, Colorado, and Jordan Rivers, where the inability of countries to manage a river in an integrated way has led to huge inequities, and in two cases, to war. The World Bank's (1993) *Policy Paper* on water resources management states (p. 45), in a section entitled "Resolution of interstate conflicts", that:

In countries with a federal structure, interstate (interprovincial) conflicts over the management of shared water resources are inevitable. Hence methods are needed for deciding among mutually exclusive proposals and for judging among conflicting claims for water rights. In some countries, interstate river basin organisations have been set up for this purpose. … Another approach is to rely on interstate agreements, which are enforceable under the country's legal system. A joint commission that guides individual state operating entities is often acceptable.

Serageldin pointed out that there are hundreds of rivers that flow through more than one country or state/province, where civil administrative boundaries do not coincide with the physical catchment boundaries. Effective management requires that arrangements be established to deal with trans-boundary issues, which introduces significant additional costs. For example, there are more than 300 international treaties which deal with international water resources, and a standard approach is to establish a river basin commission whose mandate cuts across the civil authorities' jurisdiction. Serageldin cited as successful international examples the Rhine and Danube, but there are significant costs in maintaining their river basin commissions, which provide the mechanisms for integration. He also cited a much admired (and heavily promoted) example of a sub-national river basin agency is the Murray-Darling Basin Commission, which manages and distributes the river's water in the joint interests of New South Wales, South Australia, Victoria, and the Commonwealth.

The World Bank's *Policy Paper* on water resources management (1993, p. 41) describes a "comprehensive analytical framework" that is based on the river basin as the fundamental management unit:

The framework would facilitate the consideration of relationships between the ecosystem and socioeconomic activities in river basins. In essence, this comprehensive approach breaks down very complex problems in a river basin into more manageable elements to achieve cross-sectoral water management.

The Bank's *Policy Paper* holds up as an effective approach the French system of *agences de l'eau*, commenting that it "includes many excellent features that could serve as models to help industrial and developing countries as they look for the best way to put a comprehensive approach into action". The six river basin committees and financial agencies manage water resources at the level of the river basin, and the French model progressively is being adopted in many other countries in Europe, Africa, and South America. Indeed, the European Union has promulgated an EC Directive that all members of the Union will adopt a river basin approach to water management.

Asian Development Bank

The ADB (1998) is presently finalising its *Policy on Water*, which is based heavily on the discussions of experts assembled at a Regional Consultation Workshop. Reflecting Asian experience of difficulties in achieving sustainable management of water and land, the Bank's draft policy statement is based on the concept of IWRM. It includes three principles relating to essential water management functions:

National water resource development and management should be undertaken in a holistic, determined and sustained manner to meet national development goals and protect the environment. (the word "provincial" could be substituted for "national")

Planning, development and management of specific water resources should be decentralised to an appropriate level corresponding to river basin boundaries.

Delivery of specific water services should be delegated to autonomous and accountable public, private, or cooperative agencies providing measured water services in a defined geographical area to their customers and/or members for an appropriate fee.

These principles imply that water resources should be managed on a river basin basis, while water services may be managed in an appropriate geographical area that need not be a river basin. The draft policy statement, while focussing on water resources, adopts the much more inclusive definition of IWRM referred to earlier.

The Bank has been acting on its draft policy, by emphasising the "river basin approach" in its water sector investments, including:

Hai He River, China (in which are located Beijing and Tianjin)
Song Hong River, Vietnam (in which is located Hanoi)
Several river basins in eastern Indonesia
Nam Ngum River, Lao PDR
Several river basins in Sri Lanka
Pasig River, Philippines (in which is located Manila)
Mekong River (an international river basin)

The Bank is consulting with Nepal, Philippines and Thailand to commence projects on water resources management for priority river basins in those countries. In all these cases, a key element is to introduce institutional arrangements that will enable the water to be managed coherently within a basin context.

The OECD

In its recent report *Water management: Performance and challenges in OECD countries*, the OECD (1998) adopted the inclusive IWRM model in its analysis. Most member countries are economically highly-developed and have complex water systems, and most also share rivers and aquifers with neighbouring countries. Nevertheless, the report's assessment of performance highlighted the "river basin approach" as the yardstick:

The need for better integrated management of both water quantity and quality has led to renewed interest in river basin and other "place-based" approaches. Some countries have long had river basin agencies, several are now creating them and others are considering doing so. Other countries, while not making the river basin approach a fundamental institutional feature, are improving integration by creating ad-hoc entities for the protection of specific water bodies, with representation by all stake holders.

In its summary tabulation of performance, the report included the following assessment under the heading "Integrated water resources development and management":

Programme area	Achievements	Further progress to be made
Institutional structures and legal instruments	Creation of a modern legal and institutional framework; Increasing river basin approach	Implementation, finding innovative approaches

Evidently, the OECD assessment is that adoption and implementation of institutional arrangements based on a river basin approach is to be encouraged.

Countries that already are including river basin management as a key component of new water law include Brazil, South Africa and the USA. The USA is a typical example of a country in which resource (including water) management has grown in such a way that a multiplicity of agencies with overlapping geographical and functional areas of responsibility are involved. However, the President's Clean Water Action Plan (USEPA, 1998) signals a renewed emphasis on action at the watershed level: "*as a number of states and tribes have demonstrated, they can meet existing requirements more efficiently and develop more coordinated and comprehensive priorities on a watershed basis*". Federal funding through the Clean Water and Watershed Restoration Budget Initiative and Watershed Assistance Grants provide tangible evidence of the commitment to the watershed as an appropriate unit of management.

The European Union

The European Union recently has drafted (not yet adopted) the *European framework directive for water management*, as the operational tool to implement a new European Water Policy (European Union, 1999). The Directive was the outcome of a Water Conference in 1996, attended by over 250 stakeholders spanning the full range of interests from industry representatives to environmentalists. It has a strongly environmental and ecological focus, and deals with both surface and ground water. It will require member states to establish river basin management authorities, and set out comprehensive River Basin Management Plans. The basis for this requirement is that "*the best model for a single system of water management is management by river basin – the natural geographical and hydrological unit – instead of according to administrative or political boundaries*" (European Union, 1998). Many EU countries already have adopted the river basin approach for internal as well as international rivers. The French system is the best known, but Germany, Italy, the Netherlands, Spain, Sweden, and the UK are among those with well-developed river basin approaches.

International Conference on Water and the Environment

This Conference was convened by the Government of Eire in 1992 to provide authoritative input on water-related matters to the UN Conference on Environment and Development. It was attended by 500 participants from 114 countries and 80 other organisations. Its "Dublin Statement and Report of the Conference" (WMO, 1992) has been extremely influential.

The Dublin Statement established four guiding principles, which have guided international thinking since 1992. The first was stated thus:

Principle No. 1 – Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.

Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment area or groundwater aquifer.

Expert Group Meeting on Strategic Approaches to Freshwater Management

This four-day meeting was convened by the UN Department of Economic and Social Affairs in 1998 to provide expert input to the UN Commission on Sustainable Development. It assembled 170 environmental/water specialists, most of whom were policy analysts and resource managers. It is perhaps the most up-to-date and authoritative expression of international expert opinion on freshwater management (UN DESA, 1998).

The Meeting made 25 recommendations spanning a wide range of matters; the first three (grouped together under the heading “General”) together clarify the role of IWRM and the river basin approach:

Sustainability. There is a need to recognise water as a social and economic good with a vital role in the satisfaction of basic human needs, food security, poverty alleviation, and the protection of ecosystems. The principle of sustainability must underpin an integrated approach to managing freshwater resources in order to maintain and extend the benefits derived from natural freshwater systems.

Water policy and integrated management. As recommended in Agenda 21, it is essential for all countries to develop national, and where relevant sub-national, water policies and continually review these as circumstances change. Fundamental to this process is the concept of an integrated approach to the planning, allocation, development and management of freshwater resources at the level of river basins and aquifers. The basic management unit should be designated in these policies as river basins and aquifer units.

Management of the resource. The management of the demand for, and the allocation of, water resources should be based on the principles of equity and efficient use to promote sustainable development including health, the satisfaction of basic human needs, food security and environmental protection.

OVERVIEW

International consensus

The review in the preceding section demonstrates an international consensus that river catchments and groundwater aquifers are the preferred basis for Integrated Water Resource Management and land management.

Many river catchments and aquifers have, for historical reasons, civil boundaries cutting across them. There are significant costs in terms of ineffective and inefficient resource management – for example, failure to achieve the desired environmental and socio-economic outcomes, excessive administrative costs, the costs of conflict and conflict management, the need to establish mechanisms for coordination and information exchange. The “river basin approach”, using some form of catchment management agency, is being adopted by many countries and groups of countries that have not done so already. I am unaware of any country that is dismantling such arrangements. Other approaches are possible and in use. However, at a minimum they require effective mechanisms for coordination of the various actors within a river catchment. The general consensus appears to be that these are less effective and/or less efficient (more costly), particularly in terms of conflict resolution.

The international consensus recognises that matters of civil administration are dealt with by agencies whose boundaries are likely to reflect the locations of, activities of, and interlinkages between communities of people. It also recognises that management of biophysical resources – even in the context of a particular community’s socio-economic aspirations – is best carried out within boundaries which are physically meaningful and relevant to the greatest possible number of environmental elements, and that the river catchment provides such boundaries.

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