ICIWRM – 2000, Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development, 19 – 21 December, 2000, New Delhi, India

Emerging information technology for sustainable water resources development in India

H. CHOWDHARY
Consultant, Hydrology Project, CSMRS Building, Hauz Khas, New Delhi, India
S. K. JAIN
Scientist F, National Institute of Hydrology, Roorkee, U.P., India
H. J. M. OGINK
Consultant, Hydrology Project, CSMRS Building, Hauz Khas, New Delhi, India

Abstract
Poor availability of comprehensive and good quality hydrological data and inadvertent use of inappropriate techniques leads to unsound water resources development. Non-availability of infrastructure for computerised data processing and hydrological applications has been a major cause in not employing desired solutions in the past. Developing countries like India can immensely benefit by making judicious use of the emerging information technology, which is now available at an affordable cost. The newer technologies can also improve speed and quality of decision making, presenting, and disseminating hydrological information in an efficient and user-friendly manner. Employing and absorbing the technologies with the pace with which they are evolving to develop and utilize the dwindling water resources in a sustainable manner is a formidable challenge.

The existing Indian Hydrological Information Systems (HIS) are inadequate in terms of reliability, accessibility, compatibility and presentation. These are operated by a number of central and state government agencies, often lacking desired integration, coordination and standardization. They may provide information of varying reliability, have duplications, and often long delays between observation and use/dissemination. It is essential to evolve a new HIS strategy based on latest tools. The main objective behind setting up an up-to-date hydrological database is an improved and realistic picture of the hydrology of an area. A well-designed and comprehensive hydrological-linked-geographical database will result in substantial improvement in the efficiency of the water sector and will also lead to better planning. When such data are easily and readily available, the profession would also see application of better tools.

INTRODUCTION

The period from 1960s onwards saw a rapid growth in industrial activities all over the world. It led to escalation of energy- and resource-intensive manufacturing processes and the result was faster depletion of natural resources and environmental degradation. Consequently, the environmental equilibrium was disturbed which led to a growing public awareness on related issues in 1970s. People began to realize that the earth's resources are not enough to cater for the needs of an ever-increasing population forever. The research in 1980s also led to the identification of new problems, e.g., greenhouse effect, climatic changes, and 'holes' in the ozone layer. The debate, initially confined to developed countries, began to percolate to other countries too as it was realized that these issues could not be looked into isolation.

Fresh water is one of the most critical natural resource for the continuance of life on earth. The pressure on freshwater resources has increased dramatically during the 20^{th} century. By 1997, one-third of the world's population was living under medium to high water-stress conditions, and it is expected that by 2025, two-thirds of the population will be affected *(HWRP home-page, WHYCOS project)*. Sharp growth in population in most parts of the developing world has lead to greater pressure on producing sufficient food and thereby requiring more water. Globally, about 70% of water consumed is used for irrigation; 20 % goes to industry, and 10 % for residential purposes. Inefficient irrigation practices compound the problem of freshwater availability in many parts of the world. Note that agriculture water use, though essential, has a very low net worth of produce per unit of water. For instance, in India 1000 tons of water is used to produce 1 ton of wheat worth around 10,000 rupees. But the same amount of water can be used to raise industrial output to the value of 500,000 rupees, i.e., 50 times as much. The availability of suitable water is further reduced due to growing pollution. Competition for water among neighbouring countries could become a source of conflict as there are about 300 river basins and numerous aquifers which are shared among two or more nations. Unless water resources are wisely managed, shortages could become serious obstacle to economic and social progress, particularly in the developing countries.

A necessary pre-requisite to overcome this is accurate, comprehensive and timely hydrological data along with information about the economic, social and environmental dimensions. Unfortunately, in many parts of the world, the systems for collecting and managing water-related information are inadequate, and are often deteriorating. Difficulties arise due to a lack of financial resources to maintain stations, non-uniform procedures among different agencies for data collection and quality assurance, inadequate and unreliable telecommunication systems, and outdated procedures for information management and dissemination. India is facing problems in management of hydrological information. At the same time it is being projected (Brown, 2000) as one of the countries in which millions of people will be sentenced to hard-to-handle "hydrological poverty". Further, by 2050 India will add another 519 million people (50% increase) to its side. Requirement of food grain is slated for a rise because increasing portion of Indian population will become affluent and consumes more nutrition.

The term 'sustainable development' was popularized in 1980s by the Brundtland Commission report: *Our Common Future* (WCED, 1987). It was defined as "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs". It captured then imagination of development practitioners and analysts, and rapidly displaced other buzzwords. This concept is not new; the general philosophy behind it was expounded centuries, if not millennia, earlier. Similar thoughts on living in harmony with nature can be found in ancient Indian religious texts such as *Rig-Veda*. Basically, sustainable development aims at maintaining equilibrium between human needs and economic development while conserving the environment through efficient use of natural resources. It emphasizes the need of protection of environment and is considered to be the most reasonable way of combining the current growth with planning of future projects.

Sustainable development is not top-down but a bottom-up approach. It requires that development efforts are decentralized and local people are involved in all stages of planning, design, and implementation. This term has become popular because the current development trends appear to be unsustainable in a variety of ways. Given concerns with population growth and heavy resource depletion during the past two decades, many analysts have made pessimistic predictions about the future growth of the global economy and the ability of developing countries to attain high economic levels. Some societies seem to have exceeded the carrying capacity of the land and resources to provide food and basic needs.

Information, access to information, knowledge, development policy and decision-making are imminent topics in discussions on sustainable development. "Agenda 21" (UN Conference on Environment and Development, Rio de Janeiro, 1992) underlines the need to improve decision-making concerning economic development and environmental protection at local, national and international levels (Burrows et al., 1991). Decisions taken by every human, municipal and provincial authorities, governments, multinational corporations and international organisations affect sustainable development. Agenda 21 calls for research programs and implementation of information systems that support decision-making based on sound information and procedures.

Information technology (IT) facilitates fast, cheap, equitable, and resource-efficient access to data, knowledge, and learning. A rapid exchange of data, processing, storage, and sharing without any spatial or temporal constraints facilitates people from across the globe to co-operate and collaborate. Such accessibility of data makes it an economic resource and a structuring factor in the society. Appropriate use of the knowledge by both people and machines contributes to optimum and sustainable development of natural resources. Innovative use of IT offers substitutes or lesser needs for travel and transportation, and a major shift towards less resource-intensive production, consumption, trade and services. Electronic information processing and dissemination is environmental friendly.

A giant step forward has been taken in the form of the World Bank aided Hydrology Project (HP) which aims at developing and improving the existing set-up of hydrological information systems available in various state and central agencies for eight peninsular states of India. This will assist in gathering reliable and spatially intensive data on the quantity and quality of water resources, and in utilizing computerised databases for planning, designing and management of water resources systems. Special attention is being paid to standardisation of procedures for observation and validation of data so that it is of acceptable quality and compatible between different agencies and states. Adequate facilities will be built up for proper storage, archival and dissemination of data. Infrastructure and human resources development aspects are emphasised and ensured for sustainability of such a system which should keep pace with the developments in hydrology and allied sciences.

This paper examines the above issue and suggests a change in paradigm so that the maximum benefits from the emerging technology can be obtained. The ambitious Hydrology Project is in advanced stage of implementation and the analysis has been made in the backdrop of the experience gained in setting up comprehensive and reliable hydrological information system in the country. Also highlighted are some major areas of water resources development which need to take maximum advantage of the emerging information technology.

COMPUTERISED HYDROLOGICAL INFORMATION SYSTEM (HIS) IN INDIA

In India, hydrological information is provided by various Central and State government's meteorological, surface and ground water agencies. These agencies have been using computerised methods of data handling for several years with levels of sophistication ranging from simple DOS based data files to spreadsheet files and dBase databases. However, there is lack of uniformity in the formats and software being used in different agencies and different offices of the same agencies. In general, the Central agencies are comparatively more organised than the State agencies which have limited or no computerization. The users face difficulties in getting hydrological data, specially due to difficulties in locating the source, unavailability of all data on computer media and long delays in data supply. There have been a few efforts in the past in some agencies to improve the data processing systems but these were not channelised to yield objective solutions. The HP is a concerted effort for improving and developing computerised hydrological data processing and data management systems of all the participating surface and ground water agencies.

Characteristics and Use of Hydrological Information

Hydrology, like other natural sciences is data intensive. The hydrological processes take place at a wide range of time and space scales; flood waves move at high speed while groundwater travels slowly. The land surface slope changes rapidly in the mountains while the plain areas have uniform slopes over long distances. Hence the hydrologist has to observe and analyze the data of a large number of variables at various temporal and spatial discretizations. Clearly, the design of a database given these diversities is itself a complex task. It is necessary to optimize the storage and retrieval efficiency taking into consideration these aspects.

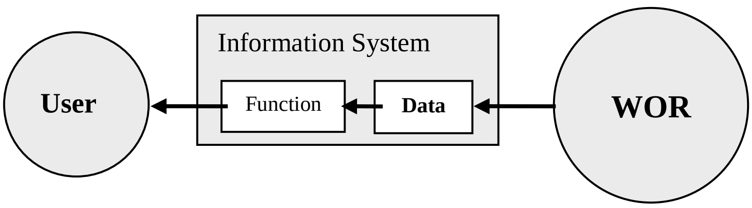

Figure 1. Representation of hydrological information system.

Another important feature of the hydrological data is the patterns of temporal variations. Consider the example of hourly rainfall values at a station. During the dry period, almost all the values are zero while during the wet season, many non-zero values are reported. This feature is a strong motivation for data compression. The search and retrieval speed is important in the design of databases. A hydrological information system is a setup to provide representative information of the hydrological process. Observed data is only the sampled view of the world (hydrological process in this case) and the functions operate on this data to obtain information. Thus users interact with the data through the functions, see Fig. 1.

Role of National Hydrological Services

National hydrological and hydro-meteorological services play a key role in formulation of national plans and coordination in relevant issues such as climate change, desertification, freshwater availability, environmental degradation, and natural disasters. They collect, store, and supply hydrological data and information for a number of uses such as:

Assessing the country's water resources (quantity, quality, distribution in time and space, the potential for water related development, and the ability to meet actual or projected demands);

Planning, design, and operation of water projects;

Assessing the environmental, economic, and social impacts of water resource management practices (existing and proposed) and adopting sound policies and strategies;

Assessing the impacts of non-water sector activities, such as urbanisation or forest harvesting on water resources; and

Providing security against water-related hazards, e.g., floods and droughts.

It needs to be appreciated that hydrological services offer substantial economic benefits. Economic value of data and forecasts can be measured by benefits such as damage avoided, better decisions, optimal design of water projects. When evaluating the benefits of hydrological information, the real value may be underestimated as it cannot be readily expressed in monetary terms. Benefit/cost ratio of hydrological data and products, such as forecasts, are considerably greater than unity; it generally varies from 1.5 to several tens. In studies conducted in Australia and Canada, the values of 6.4 and 9.3 have been reported (*HWRP home-page, WHYCOS project)*.

Upgradation/development of HIS under HP in India

The prime objective of the HP is to develop a sustainable Hydrological Information System (HIS) set up in the state surface and groundwater departments and some central agencies. A HIS comprises of physical infrastructure and human resources to collect, process, store and disseminate data on hydrological, geo-hydrological and hydro-meteorological variables. The HIS being evolved will have following characteristics:

it is demand driven, i.e., output is tuned to the user needs,
ensures use of standardized equipment and procedures for data collection and processing,
employs computerized, comprehensive and easily accessible databases, and
has proper infrastructure to ensure sustainability.

The overall objective of HIS under HP is to realize policies and strategies of the Govt. of India in the water sector. Article 2 of the National Water Policy (1987) of India which is pertinent to HIS stipulates: "*The prime requisite for resources planning is a well-developed information system. A standardized national information system should be established with a network of data banks and data bases, integrating and strengthening the existing Central and State level agencies and improving the quality of data and the processing capabilities. There should be free exchange of data among the various agencies and duplication of data collection should be avoided*".

The primary role and scope of HIS is to provide reliable data sets for long term planning and design, to frame rules for management of water resources and water use systems, and research activities in related aspects. The system is designed to provide the information to users in time and in proper form. The present scope of HIS does not provide data to users on a real-time basis for short term forecasting or for operational use. The scope of various activities under HIS is briefly outlined as under:

Assessing the needs of users: A Hydrological Data User Group (HDUG) has been constituted to respond to needs of users for each state and for the central agencies. Potential hydrological data users and the HIS implementing agencies are represented in these HDUGs. The main aim of such HDUGs is to review hydrological information needs, to identify shortfalls, and make suggestions for improvements.

Establishment/review of observational networks: After the objectives of the system are laid down, the observational network is planned, designed and established or upgraded. It has also been ensured that the observational networks of different agencies are properly integrated so that duplication is avoided. The process is to be repeated after periodic reviews.

Management of historical data: State and central agencies have maintained observational networks for many years and voluminous records are available, the majority are manuscript or chart records, which are not readily accessible. Often these are of variable or "unknown" quality. A program of historical data entry is established in each agency holding such data so as to organise this valuable information.

Data collection: Institutional, human and budgetary supports are a pre-requisite for smooth operation and maintenance of the observation stations and the associated collection of data. A network has a number of observation stations and at each station, a number of variables are observed at specified frequencies. The observations are taken manually or automatically depending upon the equipment available at the station.

Data processing, analysis and reporting: Data processing is a broad term covering all activities from receiving records of observed data to making them available in a usable form. The raw data are in a variety of formats such as hand-written records, charts and digital records. Raw data as observed and recorded may contain many gaps and inconsistencies and are passed through a series of operations, typically: data entry, validation checks, in-filling missing values, processing to estimate derived variables, compilation in different forms, and analysis for commonly required statistics etc. Most hydrological data processing activities are to be accomplished with the help of computers using dedicated software. Of particular importance is assuring the quality and reliability of the data through a variety of validation procedures. Reports are prepared to bring out the salient characteristics of the hydrological regime of the region.

Data exchange and communication: Data processing activities are carried out at many levels within each agency and this makes it essential to have adequate communication links. The meteorological and surface and groundwater networks are operated by different agencies and hence there is a need for exchange of information between these agencies for data validation.

Data storage and dissemination: All available data sets are maintained in well-defined computerised databases using an industry standard database management system. This is essential for long-term sustainability of the data sets and their efficient dissemination to the end users. Both, raw and processed data sets are stored and archived to specified standards so that there is no loss of information.

Institutional and human resources development: Since HIS is a vast system, institutional and human resource development aspect needs to be given proper emphasis. The institutions supporting the implementation of HIS must be developed such that the system is sustainable in long run. Training support is to be ensured on a sustainable basis since there will be a regular need for training.

The HIS operates at different levels from measurement in the field to comprehensive validation in State/Regional Data Processing Centres and storage in Data Storage Centres as follows:

Observation stations/wells: Data and water quality samples are collected at the surface water and groundwater observation networks. The field data are submitted to the Sub-divisional/District Data Processing Centres. The water samples are analyzed at the Water Quality Laboratories at regular intervals.

Water Quality Laboratories: After the analysis of water samples, the results are entered in the computer and subjected to primary validation. At regular intervals, the laboratory passes the information to the Divisional or Regional Data Processing Centre.

Sub-divisional/District Data Processing Centres: At these data centres, all field data are entered in the computer and preliminary validation is carried out. Computerized data are passed on to the Divisional/Regional Data Processing Centre immediately thereafter.

Divisional/Regional Data Processing Centres: Given their larger spatial coverage, advanced secondary data validation (spatial consistency checks) is carried out. After this, the surface water and groundwater data are transferred to the respective state data processing centres.

State Data Processing Centres: The main activity of these centres is final data validation, completion, analysis and reporting. After the data have been validated, the (authenticated) processed data are transferred to the State Data Storage Centre. To improve the effectiveness of the final validation, the relevant data collected by the other agencies are also used.

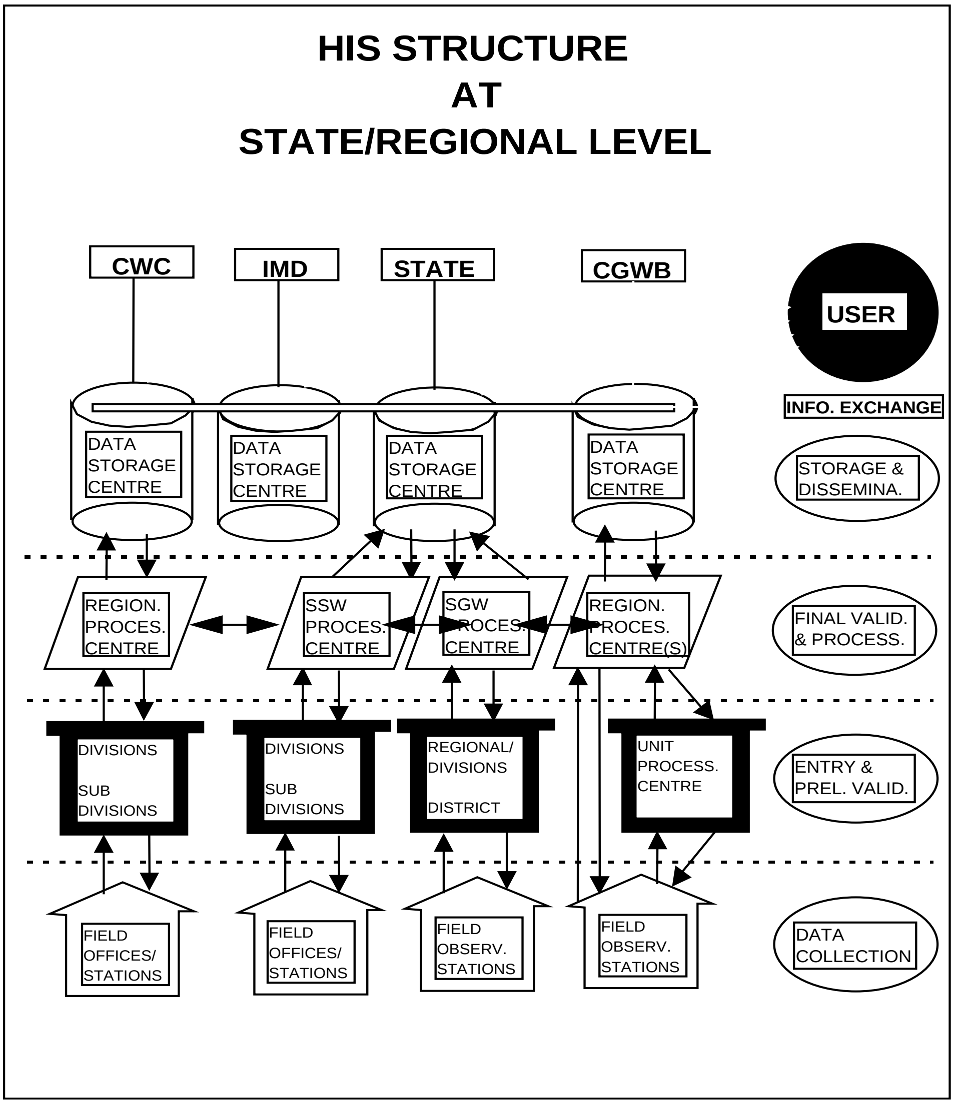

Figure 2. HIS structure at State/Regional level.

State Data Storage Centre: These store and administer the storage of all field and processed hydrological data and make the data available to authorized users. As a state archive, it also maintains a catalogue of data stored in its own database and those stored in the databases of the other agencies.

Figure 2 illustrates the structure of HIS at State/Regional level as set up by various participating State and Central agencies. The State agencies are the State irrigation/water resources departments and ground water departments, and the Central agencies are the Central Water Commission (CWC), Central Ground Water Board (CGWB) and India Meteorological Department (IMD). The key steps in establishing the State and Regional databases under HIS are:

Ensure agreement among participating states for joint commitment to the concept of HIS and its maintenance in future,
Identify user information needs and define HIS objectives,
Install improved observation systems, and train staff at all levels,
Upgrade data processing and archiving systems, and organize historical data,
Establish distributed state/regional databases,
Upgrade telecommunication network,
Monitor performance and take follow-up steps, and
Disseminate hydrological information of national and local interest.

GLOBAL HYDROLOGICAL INFORMATION SYSTEMS

There are several global observing systems and scientific programs whose aims are to monitor the state of environment, detect changes, and provide scientific data to develop appropriate strategies. These systems include the Global Climate Observing System (GCOS), the Global Terrestrial Observing System (GTOS), the Global Oceanic Observing System (GOOS) and the Global Environment Monitoring System (GEMS). In absence of a common mechanism for exchange of water-related observations, it is not possible to integrate and make use of all the observations. To strengthen the technical and institutional capabilities of various national hydrological services to capture and process hydrological data, WMO launched a program named WHYCOS (World Hydrological Cycle Observing System) in association with the World Bank in 1993 (*HWRP homepage, WHYCOS project)*.

A key element for promoting data exchange and scientific cooperation by WHYCOS is the establishment of a “global hydrological information system” using the Internet and other modern data transmission technologies. This system will be coordinated with the existing information networks and databases, at national, regional and global level. Further, to meet the aspirations of the national and regional users, the global system will enable the exchange of information with databases maintained under the family of Global Observing Systems (GOSs).

The National Hydrological Services participating in the WHYCOS programme establish sites on WMO’s World Weather Watch (WWW) to enable easy access to selected information. Raw data will be available in near-real time, although the service responsible for each monitoring station will subsequently carry out data quality assurance, according to WHYCOS criteria of data standards and timeliness. Derived products, such as maps of specific runoff, may be subject to cost recovery to generate revenue for the hydrological services. To ensure that WHYCOS data and products meet the requirements of the end users, the global system and sites on the WWW will be used to discuss results, obtain feedback, express needs, and share ideas and views.

INFORMATION TECHNOLOGY FOR SUSTAINABLE WATER RESOURCES DEVELOPMENT IN INDIA

Planning and design of a water resource development project warrants scientific use of a comprehensive information base on hydrological regime, geography and demography. Optimal performance of a project also depends upon better operational and management arrangements. Use of sensors, computers and communication system, employing the latest IT for faster assimilation and processing of information is essential to improve the project performance.

The management of natural resources requires: integration of very large volumes of information of varying reliability from numerous sources; the coupling of this information with efficient tools for assessment and evaluation and effective methods of communicating results and findings to a broad audience. The key to useful computer based decision support is integration. IT, and in particular, the integration of data base management systems, GIS, remote sensing and image processing, simulation and multi-criteria optimization models, expert systems, and interactive, symbolic and graphical user interfaces provide some of the tools for effective decision support. As a basic concept integration recognizes that in any given system for real-world applications, several sources of information or data bases, more than one problem representation or model, and a multi-faceted and problem-oriented user interface ought to be combined to provide an efficient portal. The use of IT for various aspects of water resource development is highlighted as follows:

Advanced observation systems

Efficient and automatic sensing, data logging and communication features of the hydrological and hydro-meteorological observation systems enable faster collection of data and unattended operation of remote stations for long periods. The latest electronic sensors and data loggers consume less power than the electromechanical recorders that are presently used in the country. Many Automatic Weather Stations that can measure a number of hydro-meteorological variables have been recently installed. Robust digital water level recorders (DWLRs) are increasingly being used for river stage and ground water level observations providing a near continuous record. Significant advances in the discharge measurement techniques such as the Acoustic Doppler Current Profiler (ADCP) enable gauging of some of the waters that otherwise could not be easily monitored. Some of this latest hardware has been installed under the HP. However, the major hindrance in use of these equipment is their cost and non-availability of facilities for proper and cost-effective maintenance and repair.

For real-time data use and dissemination adequate number of observation stations have to be equipped with the automated Data Collection Plateforms (DCP's) that use satellite radio transmitters to broadcast data. The concerned agencies can use the data to forecast floods, issue warnings and river condition statements, and plan reservoir releases or water withdrawals.

Integration of databases and models

The utility of organized data collection, and database management systems is well recognized. Preparation of input data is often the main effort in applied modelling. Evidently, the integration of databases and models that allow users to automatically retrieve and load input data for complex hydrological models is a natural step. For a real world problem, data comes from numerous sources, in different formats and with varying quality. Their integration into a unifying information system requires a number of tools to extract and filter, reformat and convert, inter- and extrapolate, adapt and often interpret the original data. The latest IT provides better opportunities than ever to organize vast amount of hydrological and geographical information in well-defined and open database structures. Such technology is being employed by the HP to develop databases for the participating states.

Computerized hydrological data processing system

The computing tools available now having tremendous processing speed makes it possible to use wide range of data and process it efficiently both for designing and operating the water resource systems. Some of the earlier Decision Support Systems (DSS) for the water resource projects have been marred by the computational time of the then available computerized processors. Often recourse was made to make the computations simpler and adopt greater lumping in time and space domain. Such trade-offs due to limitation of computing speed are not anymore required. Dedicated hydrological data processing systems are easily available for an effective data validation and processing. The systems being installed under the HP have capabilities for preliminary and advanced data validation and processing.

GIS and Spatially Distributed Models

GIS are tools to capture, manipulate, process and display spatial or geo-referenced data. The basic concept in GIS is one of location, of spatial distribution and relationship; basic elements are spatial objects. In hydrological modelling, by contrast, the basic concept is one of the state, expressed in terms of numbers, mass, or energy, of interaction and dynamics; the basic elements are the environmental media such as water (and water quality), sediment, flora etc.

The spatial dimensions of hydrological problems is addressed by spatially distributed models that describe the hydrological phenomenon in one (for example, in river models), two (land, hydro-meteorological, and water quality models), or three dimensions (ground water and oceanographic models). The development and use of spatially distributed models replacing simple spatially aggregated or lumped parameter models is, at least in part, driven by the availability of more and more powerful and affordable computers (Fedra and Loucks, 1985; Loucks and Fedra, 1987).

Simulation and Optimisation

Coupling of simulation and optimisation models is another example of integration of different methods. Optimisation usually requires simplification of the problem. Simulation models, on the other hand, are capable of representing desired details and complexity.

The two approaches can be combined, in that a simplified model is used as the basis for optimisation; the result of optimisation is then used as the basis for a detailed simulation model. Simulation model also keeps track of criteria, objectives and constrains used for the optimisation, but with higher degree of spatial and temporal resolution, and possibly a more refined process description. If, in the simulation run, constraints are violated or objectives are not met, the corresponding values can be tightened or relaxed in the optimisation to obtain a new solution which again is subjected to more detailed examination with simulation model.

User Interface

Apart from the internal integration, i.e., linking components of an information system, two more important dimensions to integration need to be addressed: integration with the user and integration with the sources of information. Important issues here are interaction and visualisation, intelligence, and customisation, i.e., the integration into the institutional framework of a system's intended use. Interaction is a central feature of any effective man-machine system: fast and powerful systems with modern processor technology can offer the possibility to simulate dynamic processes with animated output, and they can provide a high degree of responsiveness that is essential to maintain a successful dialogue and direct control over the software.

Visualization provides the band-width necessary to communicate and understand large amounts of highly structured information, and permits development of an intuitive understanding of processes and interdependencies, of spatial and temporal patterns, and complex systems in general. Customization is based on the direct involvement of the end-user, and the consideration of institutional context and the specifics of the problem domain in systems design and development.

Dedicated software have been developed for all types of surface and ground water data entry (called SWDES and GWDES respectively), under the HP, providing suitable user interfaces. These are specially tailored for Indian requirements and the data entry screens are similar to the forms used by the observers in the field. The software have been developed in close interaction with the users and are currently being successfully used by all offices across the project area. Such provision of common user interface is ensuring a very high level of uniformity and efficiency among various agencies engaged in providing hydrological information.

Early Warning and Decision Support System

With inexpensive sensors and wireless Internet networks, the opportunities ahead to monitor and service the complex water resources networks are very impressive (Levitt and Foster, 1999). Regular hydrological bulletin and flood warnings can be effectively disseminated using Internet based information system in addition to conventional means of communication. Various levels of flood warnings may be issued on the Internet which may instantly be triggered, if so desired, on to the computers of the intended recipients. Another example of possible integration is provided by quantitative numerical models and rule-based, qualitative expert systems. Expert systems combine the expert knowledge and can be very effective in field.

Internet based Water Information System

The Internet linked resources are increasingly being used now-a-days by many hydrological service providers to disseminate information. Internet also provides an interactive platform for the user to search information on a specific aspect of water from around the world. Additional applications include e-mail, streaming video, telephony, video-conferencing and over the next ten years, a host of applications that probably have not yet been imagined. With time the Internet and its offsprings will be faster, cheaper and better. The network technologies are likely to catalyze sea changes in the way that many organisations do their work. Some of these changes that new networks can catalyze in water sector are enhanced public outreach, data integration, organisational coordination, increasingly pervasive capability and work flow automation.

With the advent of Internet, many international databases have been set-up. WMO has established *Hydrological Information Referral Service* (INFOHYDRO) to disseminate information on hydrology. The *Global Runoff Data Centre* (GRDC) has been established at Koblenz, Germany. Organizations like USGS have created extensive databases containing data on a number of variables. Another such effort is the Internet based Watershed Information Network (WIN) developed in USA.

APPLICATIONS OF IT FOR WATER RESOURCES DEVELOPMENT

The potential application of IT in the planning, design and management of water resources projects and for hazards like droughts and floods is discussed here.

Planning and Design

This is the stage of a project that requires large amount of data and using these, the planner examines a number of alternatives to choose the most suitable. IT can help the planners in obtaining the data, organize it in the form of a database, and retrieving the data as per the needs. The planner can also search the web pages of other organizations to get the relevant information rapidly. In view of the complexity of a water resources project, it is not possible to examine the various alternatives without the help of a computer. Even on a computer, unless the analysis is performed in a systematic manner, it is possible that one may miss the optimum solution.

Management and Control Systems

Many of the water resources management decisions in India are sub-optimal because the decision-maker does not have the desired data of requisite quality to assist him. The country stands to gain tremendously if there is an improvement of even a few percent in the benefits from the water resources projects. To realize this, it is important to deploy the latest tools based on advanced technology. Such tools have been tried and tested in many countries and should be suitably modified to take care of the local conditions.

Droughts and Floods

Since drought is a creeping disaster, it can be better managed if timely forecasts about the spatial coverage and severity are available. Satellite data is proving to be very useful in this regard. The status of vegetation and water bodies can be monitored and this along with the hydro-meteorological data could provide an early warning. Such a scheme is being operationally used by some state governments in India and has been found to be effective in combating droughts.

The hydrologic conditions in a basin rapidly change during a flood event which necessitates frequent review of past decisions and updating. This requires that up-to-date data about the system are available with the decision-maker. This can be possible only with the use of automatic equipment and computer based processing and analysis of data in real-time.

PROPOSED PARADIGM

Though several institutions exist for integrated planning of water resources at the central, state and basin level, it is apparent that these institutions have not been able to keep pace with the technological development specially for providing and using the hydrological information. It is essential that a council (such as a Water Resources Information Council) is set up at the highest level to ensure availability of the latest tools and means for managing and using the water information in the country. All the crucial shortfalls presently facing the system, such as non-availability of state-of-art data processing and management system and inability to optimally assimilate and use water information for planning, design and operation of water resources projects must be addressed in the form of dedicated and time bound projects.

Such a council can have three levels of operation: planning and visionary level, project formulation and coordination level, and project implementation level. The planning and visionary level (think tank) may have highly qualified engineers and scientists and representation from other related disciplines and political and social setups. This body can make a broad agenda envisioning the strategic and objective development of water information sector in coordination with other sectors for next 20-25 years. The project formulation and coordination level ensures formulation of well-laid out projects addressing each point on the agenda and implementation while ensuring highest level of coordination with related institutions. The project implementation level can have teams of experts, drawn from governmental and private institutions from all associated disciplines, dedicated for the implementation of specific projects at hand. Such a concerted effort will ensure development of a national water resources databases and the tools for their faster assimilation and use in coordination with similar related natural resources databases.

Some of the important aspects like hydrological and other useful databases, tools like GIS, remote sensing and decision support systems which need urgent attention are outlined here. Seeking public participation and strengthening institutional capabilities while developing on above aspects would ensure broad based and sustainable development of the water resources systems using emerging information technology.

Natural Resources Database - Hydrological Data

Hydrological data on water yield, groundwater, flooding, water quality, sediment and hydrometeorological factors such as precipitation and evaporation are of prime importance for undertaking a study in any region. The existing information systems related to water in India have to be improved to provide better data storage capabilities by creating flexible and easy-to use relational databases. An inventory of available data also needs to be prepared and data catalogues are to be made widely available so that the users know what is available and where.

In the present Indian set up, the water-related information is being collected and disseminated by both State and Central agencies, almost independently. Though the roles of Central and State agencies in providing hydrological information is complementary to each other, there is an urgent need for desired integration. It is desired that States and Central agencies have independently maintained distributed data bases and a central catalogue to tie these local sites together and serve for a national hydrological information program.

Topographic and Demographic Data

Land characterization in terms of its use, soil characteristics, and terrain information is essential for any meaningful hydrological study. The land use features undergo changes with time and thus this data has temporal and spatial properties. Acquisition and analysis of this data becomes very easy with the help of satellites, computers and GIS systems. Most of the topographic maps that are available today are more than 30 years old. The updating of these maps is extremely important but it requires large efforts and the emerging IT can be very helpful in realizing this goal.

The socio-economic and demographic data is also very important in water resources planning and management. Again due to the numbers of variables involved and the volume of data, it can be best managed by the use of latest IT tools.

Remote Sensing and GIS Tools

These tools have been around for quite some time but in view of rapid and wide spread penetration of computers in the last few years, the developments and applications of these have multiplied many times. The remote sensing technology is now being applied operationally too. As for GIS tools, though the application is growing, it is mostly for organizing inputs and outputs and sometimes in modelling. However, the indicators do point towards widespread application and realization of its power in water resources management.

Decision Support Systems

Interdisciplinary teams including software engineers should identify functional and user requirements and develop application programs to solve problems at municipal, national and global levels. The DSS require the application of the full potential of advanced computer technologies – telecommunication, multimedia, geographic information system, expert systems, modelling, and natural language processing. It is a challenge to integrate a wide range of applications and develop interfaces between systems from different application domains.

Public Involvement

The evaluations of many past projects have shown that poor identification of the needs of local communities and inadequate assessment of social impacts are the key reasons for project failures. An important pointer is more rigorous pre-project analysis of social and cultural conditions and interaction/consultation with local communities during project design and implementation. Local residents with deep knowledge about the area can sometimes provide better inputs than ‘an outsider planner’. The United Nations (UN, 1997) has laid special emphasis on Public Involvement (PI) in water resources projects. PI is the process through which the views of all interested stakeholders are integrated in decision-making.

Except through the politicians and non-governmental organizations, generally there is no worthwhile PI in water resources planning activities in many countries. In some cases this has led to serious problems during the execution of the projects. In a few countries, PI is ensured through public hearings. While the underlying principles of PI are applicable to all countries and all natural resources projects, the mechanism and degree of PI vary considerably from one society to another and from one project to another. Due to its wider penetration, Internet can be very effective in this effort. It can be used to disseminate information as well as to get peoples reaction, opinion and to carry surveys. This can result in substantial saving in time and efforts.

Institutional Strength

Institutional integration must also look at aspects such as user training, data entry, maintenance issues of keeping systems current and operational, providing adaptations and updates, etc. Any complex information system has more than one user at more than one level of technical competence and with different roles within an institution. Different users have different requirements that need to be supported: flexibility and adaptability are therefore important features. Systems must be able to grow with their users. Therefore, the institutional commitment and technical infrastructure to keep a system alive and evolving are as important as the scientific and technical quality of the object system.

It is essential that water resources and IT community continue to effectively interact with each other. Three ideas can be considered: (a) required, preparatory course work in electronic communications for all prospective water sector professionals, (b) short courses for established water resources personnel unfamiliar with new technology, and (c) identification of potential “translators” in research institutions or consulting firms who can serve as advisors and trouble-shooters for managers and policy makers. Those electronic, communications, and data management professionals who seek to work with water resources groups should, in turn, be encouraged to learn the basics of water resources field.

CONCLUSIONS

Many national hydrological services, particularly in developing countries, do not receive adequate funds for even basic monitoring and assessment of the status and trend of national water resources. The situation is exacerbated by the existence of several monitoring networks in a country with different purposes and standards; these are often independently operated. In large parts of India, collection and dissemination of water-related information have been neglected in recent years. When stations malfunction, they are closed due to lack of resources for repair or spares. Computer archives do not exist or are maintained on obsolete equipment, and paper records are fast deteriorating resulting in long gaps in records and their unknown quality. This drastically reduces their value for design, assessment of trends, or informed planning and management. This is seriously restricting the ability of the nation to address the issues in right perspective. Better, but not necessarily more, information directly useful to a larger number of participants in more open and participatory decision making processes is urgently needed.

Recently, the expansion of water-development projects has slowed due to stringent environmental norms and other reasons. The optimal use of existing water-resources infrastructure is very important now. A pre-requisite for any water resources development and management plan is the availability of a comprehensive, reliable and easily accessible hydrological information system. India has already established herself in the IT area. There is no reason why this technology can't be extensively applied in water sector. Historically we are at cross-roads. There are great challenges in water sector and unless these are faced head-on with the best tools now, a similar opportunity may not come in the foreseeable future.

References

Brown, Lester R. (2000). Population Growth Sentencing Millions to Hydrological Poverty. Report of Worldwatch Institute, Massachusetts Ave., NW, Washington, DC.

Burrows B., Mayne A., Newbury P. (1991). Into the 21 Century: A Handbook for Sustainable Future, Adamantine Press Ltd.

Fedra, K. and D.P. Loucks. 1985. Interactive Computer Technology for Planning and Policy Modelling. Water Resources Research 21 (2); 114-122

HWRP home-page, WHYCOS Project. (2000). World Hydrological Cycle Observing System, Hydrology and Water Resources Programme, WMO.

Levitt, J. N. and C. H.W. Foster. (1999). Water Resources and the Internet: A New England Perspective. Symposium on Water Resources and the World Wide Web, Seattle, USA, Dec. 5-9.

Loucks, D.P. and K. Fedra. (1987). Impact of Changing Computer Technology on Hydrologic and Water Resources Modelling. Review of Geophysics, 25(2), March.

UN(1997). Public Involvement Guidelines for Natural Resources Development Projects, The United Nations, New York.

WCED (1987), Our Common Future (The Brundtland Report), World Commission on Environment and Development, Oxford University Press, UK.