

Upgrading a conventional hydrological information system—an Indian example

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Abstract The existing hydrological information systems in many countries lack reliability, accessibility and timeliness. The main causes are substandard observation practices, manual processing, the wide gap between the tools available and those employed, and the involvement of many agencies, often lacking integration. A comprehensive computerized hydrological–geographic database is the key to efficient water management. An attempt to improve the existing systems in nine peninsular states of India is underway through the Hydrology Project. The prime objective of the Hydrology Project is to standardize data collection and processing and develop a hydrological information system (HIS). Infrastructure development, maintenance, and training of personnel are emphasized to ensure sustainability. The key features of HIS and experiences from revitalizing the existing system over a region of about 1.7 million km² are highlighted.

Key words hydrological information system; hydrological data; data processing; India

INTRODUCTION

A necessary pre-requisite for wise water management is accurate, comprehensive, and timely hydrological data. Unfortunately, the systems for collecting and managing water-related data in many countries are inadequate and often deteriorating. Difficulties arise due to lack of funds, non-standard procedures for data collection and quality assurance, and outdated ways for data management and dissemination. To improve the existing hydrological information system (HIS) in India, a giant step has been taken by launching the ambitious Hydrology Project. The Hydrology Project aims at developing and improving the existing HIS of various government agencies in nine peninsular states of India: Andhra Pradesh, Chhattisgarh, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Kerala, Orissa and Tamil Nadu (Fig. 1). This will assist in gathering reliable and spatially intensive data on water quantity and quality and storage of this data in computerized databases. Special attention is being paid to standardization of procedures for data observation and validation so that data are of acceptable quality and compatible across agencies. For sustainability of the system, attention is being given to the infrastructure and human resources development, which should grow with developments in hydrology and allied technologies.

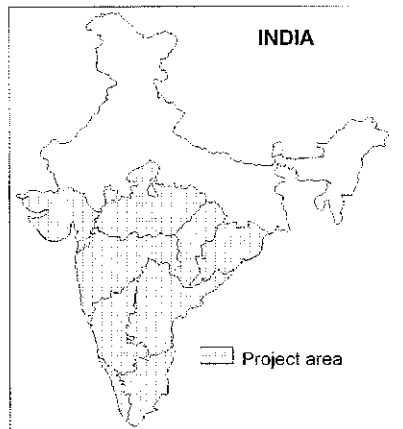


Fig. 1 Nine Indian states that participate in the Hydrology Project.

This paper highlights the salient features of the improved HIS. The Hydrology Project is in an advanced stage of implementation and an analysis has been made on the experience gained so far. Also proposed are some plans as a follow up.

EXISTING HYDROLOGICAL INFORMATION SYSTEM IN INDIA

Hydrological data in India are primarily provided by various Central and State Government meteorological, surface water, and groundwater agencies. Information on surface water is provided by the Central Water Commission (CWC) and state water resources departments; information on groundwater is provided by the Central Ground Water Board (CGWB) and respective state groundwater agencies. The responsibility for quality data lies with Central/State Pollution Control Boards, Public Health Engineering Departments, CWC and CGWB.

Observation networks

Rainfall stations constitute the bulk of the hydrometeorological network and are mainly owned by the state departments. The India Meteorological Department (IMD) collects and archives data from selected stations. The climate stations are mainly maintained by IMD. Unfortunately, most of the rainfall stations are quite old (ranging from 20 to 100 years old) and many of these have not been adequately maintained and upgraded. Though the observation networks of the central and state agencies are expected to play complementary roles, the actual networks often have duplications and gaps.

River gauging stations have primarily been set up to collect water level, discharge and sediment data at important locations. CWC stations are located on the major rivers whereas those of the states are on tributaries and smaller rivers. CWC mainly gathers data on overall water resources of the country for planning major projects, to resolve interstate water sharing, and for flood forecasting. The networks of state agencies

cover the basins more intensely and provide data to plan and design small and medium water resources projects. Coupled with ever-reducing financial support, the shortage of trained observers has rendered many river gauging and meteorological stations non-operational. The observation process on most stations is manual though in a few instances automatic equipment has been installed recently. Velocity measurement is mainly by current meters at CWC stations; the use of floats has been in vogue in many states.

The assessment of groundwater resources in India is based on annual recharge and discharge using the water balance equation. Most groundwater observations have been at open dug wells that tap the upper unconfined aquifers; the measured water levels represent the piezometric head of the semi-confined/unconfined aquifers. However, the necessary well-aquifer hydraulic connection is not always confirmed. Usually, observations are taken four times a year and are assumed to represent the troughs and peaks of the water table hydrograph. Clearly, four data points are too sparse to yield reliable conclusions. Limited monitoring of the piezometric head of the deeper confined/leaky confined aquifers has been carried out by some agencies.

Awareness about the need for collecting water quality data has grown only in the last decade, primarily due to deterioration of resources. Whereas the river gauging authorities take samples at the gauging stations, the pollution control boards undertake surveillance near industrial or urban centres. In the past, water quality laboratories were inadequate in terms of numbers, financial support and capabilities.

Data processing and dissemination

Computers have been in use in India for handling hydrological data for quite some time with different levels of sophistication ranging from simple ASCII based files to more user-friendly spreadsheet files and databases. However, there is a lack of uniformity in the formats and software used by different agencies and even in different offices of the same agency. There have been sporadic efforts in the past to improve the data processing systems but these were not designed to yield objective solutions.

SALIENT FEATURES OF THE NEW HIS

The prime objective of the Hydrology Project is to develop a comprehensive, reliable, user-friendly, and sustainable HIS. A HIS comprises of a physical infrastructure and the human resources to collect, process, store, and disseminate water resources data. The primary role and scope of HIS is to provide reliable data for planning, design, and management of water resources and for research purposes. The new HIS is conceptualized and set-up through the steps described below.

Review of observational networks

The existing observational networks have been thoroughly reviewed from three viewpoints:

- (a) to open new stations in areas hitherto inadequately covered or to replace non-representative stations,
- (b) to avoid duplication of stations across agencies, and
- (c) to improve the frequency and accuracy of observations through standard equipment and procedures. Old and defunct equipment has been replaced with standard equipment. A comprehensive list of equipment has been drawn up and detailed specifications made.

There were about 7200 rainfall and 640 climate stations in the project area (Hydrology Project, 1995). Inspections revealed that improperly located stations, ill-maintained or defunct equipment, and substandard observation practices were quite common. A major improvement in the hydrometeorological network has been the reactivation of these non-functional rainfall stations. Adding 500 new stations and upgrading another 1700 have revitalized the meteorological network. Many new climate stations have also been set up.

The main improvements of river gauging stations have been the introduction of digital water level recorders and replacing floats with current meters. About 265 existing stations have been upgraded and another 650 new stations have been established. Sophisticated techniques for discharge measurements like acoustic Doppler current profilers have also been employed, on an experimental basis, at a few stations where gauging by conventional means is extremely difficult.

Previously, there were about 27 000 groundwater observation wells in the project area of which about 6% were tube wells while the others were open dug wells. These were not properly maintained. The network has been strengthened by adding about 7900 purpose-built, non-pumping observation wells to facilitate measurement of the vertically averaged piezometric head of a selected single layer. These are also being used for water quality monitoring. The network has been optimized to give a good spatial and vertical coverage by integrating piezometers of different agencies. As many as 6400 piezometers have been equipped with digital water level recorders to enable measurement of head at the desired frequency. The accurate and high frequency data will facilitate many new analyses.

An extensive network for monitoring surface water quality at about 675 locations and groundwater at about 29 000 locations has been established. Stations are categorized as "Baseline", "Trend" and "Flux" stations based on guidelines similar to those of the World Health Organization (WHO, 1992). The sampling frequency and water quality parameters analysed for each category of stations have been defined and documented (Hydrology Project, 2000a) for ensuring uniform monitoring procedures are used.

A comprehensive water quality laboratory development programme includes establishing/upgrading 290 laboratories under three categories: Level I, Level II, and Level II+. As many as 215 Level I laboratories cover six field parameters (colour, temperature, pH, dissolved oxygen, conductivity and turbidity). Another 50 Level II laboratories are for analysis of physico-chemical and microbiological parameters. The remaining 25 Level II+ laboratories undertake additional analysis for heavy metals and pesticides. Special instruments like ultraviolet-visible spectrophotometers, atomic absorption spectrophotometers, and gas chromatographs have been provided for identification of toxicants, trace metals, pesticides etc. The analysis procedures have

been documented (Hydrology Project, 2000b) with illustrations and sample calculations. An analytical quality control programme ensures reliability and reproducibility of data across the laboratories.

Data processing, analysis and reporting

The existing manual system of data processing is being replaced by dedicated and user-friendly computerized systems. The raw data are in a variety of formats such as hand-written records, charts and digital records and contain gaps and inconsistencies. Hydrological data processing software HYMOS developed by Delft Hydraulics, The Netherlands, is employed for all surface water analyses. Comprehensive groundwater data processing software is also being prepared. Both software packages are modular and are being implemented with varying levels of sophistication. The first module is dedicated to data entry and preliminary validation. The second module focuses on spatial consistency checks, data correction, compilation, and analyses. The highest-level setup has modules for hydrological validation and comprehensive reporting. The application of this system has, for the first time, enabled the processing of all the hydrological data at a gigantic scale using uniform tools. Use of these tools in the field ensures immediate feedback to the stations in the case of observational errors.

Management of historical data

A huge volume of historical data, mostly in manuscript or chart form, is available. Often, these data are of variable or “unknown” quality since in many cases the recorded data were seldom scrutinized. For each agency, a comprehensive programme of historical data entry and processing has been prepared. Such a mammoth organization of hydrological data is being accomplished for the first time in the country. This provides an excellent opportunity to easily access and use historical hydrological information.

Data storage and dissemination

It is proposed that all historical and current data should be stored in well-defined computerized databases using standard state-of-the-art relational database management systems. Both raw and processed data will be stored to avoid loss of information. Typical features of data administration like security, protection from corruption, and controlled accessibility would be implemented. An efficient system with graphical visualization on maps for identifying the required data, also through the Internet, is envisaged.

Assessing users’ needs

Hydrological data user groups consisting of a wide array of potential users have been constituted in each state and at the central level to ascertain the user needs. The main

aim of hydrological data user groups is to review the requirements for hydrological information, identify shortfalls and suggest improvements.

OVERALL STRUCTURE OF HIS

The structure of HIS at state/regional/national levels, emphasizing the distributed data processing, exchange, and dissemination is illustrated in Fig. 2. Each data processing centre (DPC) has adequate communication links for exchange of data with other DPCs. From data observation to final storage, HIS operates at different levels in the following way:

- The observed field data are submitted to the sub-divisional/district/unit DPC (SDDPC/dDPC/UDPC) at the end of the month of observation. They are entered and preliminary validation is carried out within 10 days. The data are then passed on to the divisional/regional DPC (DDPC/rDPC). The water quality samples are regularly sent to designated water quality laboratories. Samples are analysed within the prescribed time frame. The results are entered in the computer and subjected to primary validation. At regular intervals, the laboratory passes the data to DDPC/rDPC.
- Given their larger areal coverage under DDPC/rDPCs, data are organized in basin wise databases and secondary validation (spatial consistency checks) is completed within 15 days of receipt of data. The data are then transferred to the respective

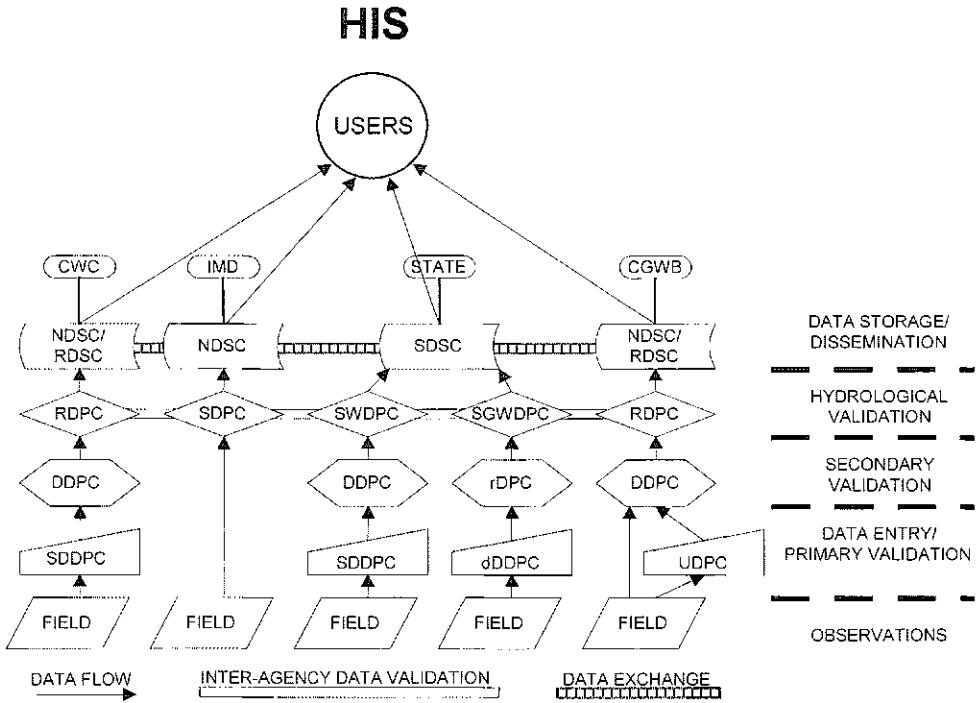


Fig. 2 HIS structure at state/regional/national levels.

state/regional DPC (SDPC/RDPC). The main activity at SDPC/RDPC centres is hydrological data validation, completion, analysis, and reporting. Inter-agency data validation exercises are scheduled twice a year: in February (for the data of monsoon months) and August (non-monsoon months). Next, the processed data are transferred to the respective state/regional data storage centres (SDSC/RDSCs).

- Seven out of nine states have a common DSC for surface water and groundwater data. Central agencies have separate DSCs for each region. Each central agency also has a national DSC (NDSC) for an overall perspective of the hydrological regime at national level. All the SDSC/RDSCs store and administer the field (or raw) and processed (or authenticated) data and ensure smooth dissemination to the users. The DSCs function purely as a hydrological data library equipped with a catalogue of stored data. A strict distinction between the DPCs and the DSCs is emphasized for ensuring sustainability and maintenance of finalized databases for future reference and use.

SUSTAINABILITY OF HIS

An extensive training programme is being implemented to develop the skills of the personnel involved in HIS. The subjects and activities covered include: (a) observation practices for hydrological and allied data, (b) surface water, groundwater, and water quality data entry and processing using dedicated software, (c) GIS and database management systems, (d) water quality sampling and analysis, (e) procurement and installation of equipment and other infrastructure facilities, and (f) training and communication skills.

Most training courses have been through designated research and academic institutions called the Central Training Institutes (CTIs). A three-pronged approach is being followed to impart training to a large number of trainees (about 10 000) by employing the concept of “training of trainers”. A core group of motivated officers are trained who in turn are expected to train the actual trainees. Trainees are further assisted at their work place by “hands on sessions”. Comprehensive training documents including exercises and presentation material have been prepared to ensure uniformity and standardization in delivery of training courses.

PROJECT IMPLEMENTATION

Implementation of any widespread project like the Hydrology Project, involving more than 20 agencies, requires meticulous planning. The Hydrology Project is being satisfactorily implemented by most of the agencies. However, a retrospective appraisal brings out certain factors, which might have given better results, such as: (a) careful preparation of specifications of sophisticated equipment taking into consideration local conditions, (b) realistic accounting of the time required for government procurement process, (c) ensuring the availability of infrastructure facilities before delivery of equipment, (d) synchronizing training with the availability of staff, computers, and

readiness of observation stations, and (e) training of existing staff for specialized jobs rather than wait for recruitment of new staff.

The project is unique for standardizing equipment specifications, setting uniform and standard data collection procedures, providing structured training and implementing software for data processing and management at such a gigantic scale. Besides the successful implementation during the project period, it is also crucial to ensure HIS activities are sustained in the future. Two major factors which may impede this are the frequent transfers of officials and inadequate budgetary support.

CONCLUSIONS

A comprehensive, reliable, and easily accessible HIS is a pre-requisite for optimally utilizing the available water resources. The Hydrology Project in India is a concerted effort to improve the existing system and provide a computerized HIS ensuring efficient dissemination of information. Augmentation and upgrading of various networks has provided fresh impetus to the (geo-)hydrological monitoring in the country. It has led to improved spatial and temporal coverage and data of better quality. The upgrading and augmentation of the network may affect the homogeneity of data; this is to be ascertained when sufficient data become available. Data processing with a decentralized hierarchical structure ensures a completely participatory approach. The system promotes greater interaction between different HIS agencies and also ensures uniformity of tools and procedures used. Such standardization will help solve water disputes now and in the future. Improvements in infrastructure and institutional support are beginning to be reflected in terms of the availability of organized hydrological databases and timely availability of better quality data to the users. It would only be fitting that the improved system continues to grow and the experience gained is utilized for similar improvements elsewhere.

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