COPING WITH NEW CHALLENGES IN WATER RESOURCES MANAGEMENT

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ABSTRACT

One of the most stressed resources in India is water. Major challenges facing sustainable water resources management in the country today include: increasing vulnerability to extreme events, unrestricted extractions, growing urban demand, climate change, land-use changes and environmental requirements. In this context, the study gives an overview of existing water management practices in the country; and elucidates the role of hydrological services including focused R&D in resolving water resources issues. Recent efforts in enhancing institutional capacity for decision making is elaborated in the context of implementation of World Bank aided Hydrology Project. R&D efforts in water sector are shown to embrace two major roles in furthering sustainable water resources management: i) helping to decrease the vulnerability by furthering development and increasing adaptive capacity, and ii) giving an option to respond to numerous contingencies that an unknown future holds.

1.0 INTRODUCTION

At the beginning of 20th century, the population of India was approximately 24 crore; which rose to 103 crore at the beginning of 21st century, and to about 122 crore today. With the growth of human population has come the increased need for resources to sustain the multitude. Food and water are two of the basic human needs; and the latter, in the form of irrigation, is necessary to produce much of the former. As world population increases, a catastrophe as predicted by many thinkers may or may not befall on the human race, but one thing is certain: what we get would be increasingly difficult choices, especially as regards water resources management, which can only be dealt effectively by the best available technology [1, 2].

Modern technology has contributed immensely to the sustenance of population of the country at present level. Issues such as climate change, land-use changes, growing urban demand and environmental requirements continue to influence adversely sustainable water resources development and management. Research and development (R&D), often referred as the engine of prosperity, provides the underpinning for use of best available technology in water sector, and optimum use of available resources. It can safely be said that the one and only way to circumvent water-related issues is manifold increase in technical innovation to facilitate optimum utilisation of scarce resources; which in practice trickles down to increased R&D efforts in the water sector.

In the above context, this study takes an overview of existing water management practices in India; and identifies the major challenges facing water management today. Further, the role of hydrological services is focused on, including the need for targeted R&D. Recent efforts in enhancing institutional capacity for decision making are brought out in the context of implementation of World Bank aided Hydrology Project, wherein CWPRS is one of the Implementing Agencies. R&D efforts in the sector are shown to assume two major roles in furthering sustainable water resources management: i) helping to decrease the vulnerability by furthering development and increasing adaptive capacity, and ii) giving an option to respond to numerous contingencies that an unknown future holds.

2. WATER MANGEMENT AND KEY ISSUES

2.1 Background

Temporal and spatial distribution of rainfall in our country is highly skewed; with about 80 % rains falling during three monsoon months in most parts of the country. Water resources are under increasing competition because of burgeoning population with increasing affluence demanding more water in the form of agriculture, industry, domestic and hydropower needs. Water management for the society today is very complex, and involves diverse activities that are administered by different players. Major components constituting present day water management are classified below.

- *Water Allocation:* Apportioning of water to major users and uses; maintaining minimum levels for social and environmental use, while addressing equity and development needs of society
- *River basin planning:* Preparing and updating the basin plan as per need by incorporating stakeholder views on development and management priorities for the basin
- *Stakeholder participation:* Implementing stakeholder participation as a basis for decision making that takes into account the best interests of society and the environment in the development and use of water resources in the basin
- *Pollution control:* Managing pollution using socially acceptable principles and appropriate incentives to mitigate environmental and social impacts
- *Monitoring:* Implementing effective monitoring systems, which provide needed management information to identify and respond to infringement of laws/ regulations/ permits.
- *Economic and financial management:* Applying economic and financial tools for investment and cost recovery to support the goals of equitable access and sustainable benefits to society
- *Information management:* Providing essential data necessary to make informed and transparent decisions towards sustainable management of water resources

2.2 Existing Practices

The above-mentioned activities, generic to water management in the country, are beset with a number of challenges that put these services at risk. India is undergoing rapid economic development and urbanisation; with the current water development and management systems proving to be not sustainable. Lack of adequate storage is a major challenge in water resources development. Consequently, groundwater resources are being increasingly used, even to the extent of over-exploitation. Groundwater constitutes over half of India’s total water use; with 70 % irrigated areas and 80 % domestic water supply depending on groundwater. More than 15 % of India’s food is estimated to be cultivated using non-renewable, mined groundwater.

Water data are collected by different agencies in India, and stored at varied locations, with no common umbrella available. This leads to difficulties in accessing all relevant data by employees in different departments. Some states make limited amounts of information available to the public; resulting in politicians, domestic, industrial and agricultural users not making optimal decisions due to a lack of information. This can exacerbate water resources issues.

Another challenge is the disconnection between management of surface water and ground water. Experts/ administrators in each field are usually located in different departments, with different management structures. Further, the data management tools used are often different for surface and ground water. For example, in India the application software SWDES and HYMOS are used for surface water analyses; and GWDES and GEMS for ground water. This makes it difficult for the state agencies to derive the most value from their water, with surface and ground water resources not considered together.

Apart from additional storage, there is an urgent need for improved management of water resources at all levels [3]. Irrigation management is a case in point, where potentially large reduction in quantum of water use is feasible. A framework of agricultural, engineering and socio-economic measures is needed for effecting and efficient use of irrigation water supply. Agricultural measures include: deep cultivation, developing crops resistant waster stress, improving soil moisture availability and staggering of water requirement for the crops. From socio-economic point of view, we need to see water as an economic good for which a rational price may need to be attached to protected water supply, similar on the lines of power supply. Further, users of irrigation water need to be protected by maintenance of an effective system of legally enforceable water-rights and other water-legislation.

Engineering measures are simultaneously needed to be enforced for sustainability in irrigation water supplies. Such measures include: periodical risk analysis, integration of small reservoirs with major reservoirs to ensure that benefits are maximised, improving efficiency of water conveyance system by better operation and maintenance procedures including rehabilitation and modernisation measures wherever warranted. This warrants planned implementation of lift irrigation schemes in association with canal-water supplies; and conjunctive use of surface and ground water helps in combating water-logging and salinisation of farm-land.

2.3 Need for Hydrologic Design Aids and Generic DSS Models

Skills and knowledge are built up in individuals through years of experience and `on-the-job' training. Modelling expertise within states tends to be limited to a few individuals. This expertise allows water resources managers to operate their systems using engineering judgement, often based on a highly developed `feel' for the situation. When managers want to run test scenarios for short-term planning or to test the feasibility of infrastructure projects, they are fully reliant on the skills of a few modellers available at that time. When key personnel are lost due to factors such as transfer and retirement, the expertise is often lost irretrievably. Individual managers and technicians who are entrusted with water management functions at central/ state/ other agency levels do generally a good job in operating often complex systems to deliver best services to a wide range of users.

Good managers and technicians are no substitute for improving and systematising water management practices through good, generic decision support system (DSS) models that can address issues such as providing access to common data; enhancing institutional capacity for decision making; publishing key data to inform the general public; and assisting short and long term planning through modelling [4]. DSS systems gainfully employed in water management include: simulation models for surface water planning, reservoir optimisation with forecasted stream flows, drought monitoring/ assessment, flood forecasting and management and integrated water resources management. Section 3.1.3 details certain focused national efforts in this direction.

One issue that irks water management in India is the low use of data in design of projects. Very often, designs of projects are done by empirical/ rational methods. The principal reasons for this approach are: difficulties in accessing all relevant records, processing and analysis, absence of specialists such as hydrologists and hydrogeologists in design offices and lack of established design aids.

2.4 Water Management Issues

Coupled with problems co-existing with present-day water management practices afore-described, modern-day water resources management is beset with the following key issues arising from the vagaries of hydrologic cycle and other extraneous factors [5].

Increasing Vulnerability to Severe Events:
Inter-Governmental Panel on Climate Change (IPCC) highlights the potential for more frequent and more severe weather conditions; which is corroborated by many instances of extreme hydrological events [such as heavy snow storms in Himalayan valley, Europe and elsewhere in Feb 2012, Jul 2005 storm event in Mumbai, etc.]. Such eventualities, coupled with increased pressure on land from the increasing population, will make safety of life and property high on the agenda for administrators and planners [6].

Urban Demand:
More than 70 percent of Indian population is projected to live in urban and semi-urban areas by 2015. People, and the ever-growing industrial sector, will demand an increasingly larger share of the total water available; much of which is liable to be diverted from water meant for irrigation; which in turn can place greater pressure on water supply systems, and reduce availability of arable land. Accelerated urbanisation has also the potential to create substantial pollution load on freshwater supplies and estuaries, which needs to be addressed. With urbanisation comes the problem of the less privileged in the society often flocking to flood plains of rivers, thus creating additional technological and socio-economic issues concerning flood management.

Unrestricted Extractions:
Often, there is neither a management plan nor restrictions on water extraction from scarce resources. Water being the ultimate *'commons'*, and since water resources are no longer boundless, communities need to study water systems and re-define wise use [7]. Changes in human values, and ideas of morality, are needs of the day as regards water usage to avoid a situation where rational pursuit of individual self-interest can lead to collective ruin. Ground water extraction in large parts of India is a classic example in this respect.

Climate Change:
In general, analyses and application of management techniques in water sector have all along been carried out based on the presumption that hydrological series are stationary. There is growing evidence of shifting trends in such series, which need to be assessed and ascertained to enable taking corrective actions as needed. Periodic review of hydrometeorological networks for arriving at optimum network also assumes significance in this respect, as brought out under section 3.1. There is growing evidence of warming climate, as spelt out by climatologists, which can spell misery to the population in such regions. IPCC warns that climate change is expected to exacerbate water scarcity situation in Asia, with consequential multiple socio-economic stresses.

Allocation Problem of Existing Supplies:
A typical water-supply system to a city involves structures such as reservoirs, canals, pumping systems, pipes, etc.; which are generally designed and allocated on the basis of past availability and existing demands. The current and/ or future availability does not often form a part of the scheme of things. This makes many water supply systems over-allocated. Studies show that, in general, lower the data length, higher is the likelihood of over-estimating water resources availability in a region. Uncertainties in respect of flood potential assessment too increase. Such factors warrant review of allocation of water supply systems and safety aspects from flood hazards periodically [8].

Land-use Changes:
Land use change is a reality, with more forest/ arid/ marshy/ fallow areas paving way for activities such as mining, agriculture, tourism-related activities and infrastructure development. For instance, a large number of mega power projects coming up on the eastern coastal region of India. Expanding plantations and decreasing forest cover also play a major part in this scenario. Changes to land use, even within agricultural lands, have substantial implications for both water availability and use.

Environmental Requirements:
Environmental concerns are foremost on the minds of administrators, planners and the general populace; with the result that there is a steadily increasing awareness and emphasis on the requirements of environmental flows in any river system towards maintaining ecosystems such as wetland and in-stream environs. We have begun accepting the rights of nature, treating rivers, estuaries, forests and the like not as simply properties, but entities who have their own right to flourish. The day is not far of wherein this right would be put into statute, which would enable a vigilant citizen to file a suit on behalf of, say the injured watershed, arguing that its health is crucial to the common good [9].

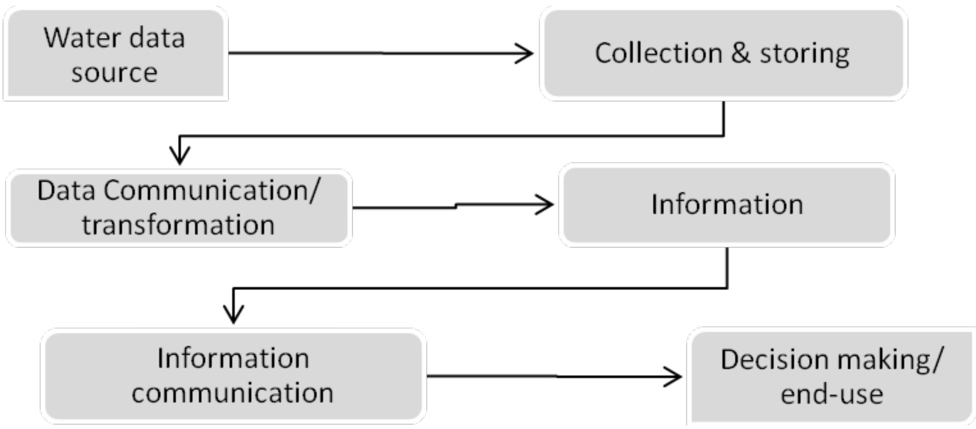
In the above context, the ensuing sections detail the wherewithal to counter the issues by sustained scientific and technological initiatives in the hydrological services regime.

3. HYDROLOGICAL SERVICES

3.1 Monitoring, Analysis and Assessment

The value of information for sustainable water resources development is self-evident. Information is a product of basic data, operated upon by mathematical, statistical, hydraulic, hydrological and other optimisation models. Specific information to be produced would depend on recognition of the problem, and its subsequent solution using the relevant model(s). If the database is well designed and the models well documented, the same data can produce different varieties of information, with each one capable of being used in different situations.

Hydrological information system (HIS) forms the backbone of water resources activities for a country; providing reliable data for long-term planning, design and management of resources and water use systems, and for research activities in related areas. In India, primary data for HIS are collected, processed, stored and status reports brought out by agencies such as Central Water Commission, India Meteorological Department (IMD), State Irrigation/ Agriculture/ Public Works/ Water Resources Departments, etc. HIS, in practice, comprises data collection and storing system, data communication/ transmission system, data transformation system for producing information and information communication system, which in turn leads to inputs to informed decision making by the end-users, as delineated below.



Hydrological Information System

Data transformation is in practice done by models, which can range from simple statistical models, hydrologic design aids, nomograms, involved DSS models and the like. HIS is central to sustainable water development, with its output having a wide variety of users, both in the public services domain and in private sector. Users fall under the broad clusters of large scale and repeat users, and occasional or one-time users. A majority of the users in the public services domain belong to the former; whereas, most users in the private sector are likely to belong to the latter category. For instance, CWPRS is a sophisticated user of water data; with the organisation using data extensively in physical, mathematical, hydraulic, hydrologic and other models while conducting applied/ specific research studies pertaining to water resources.

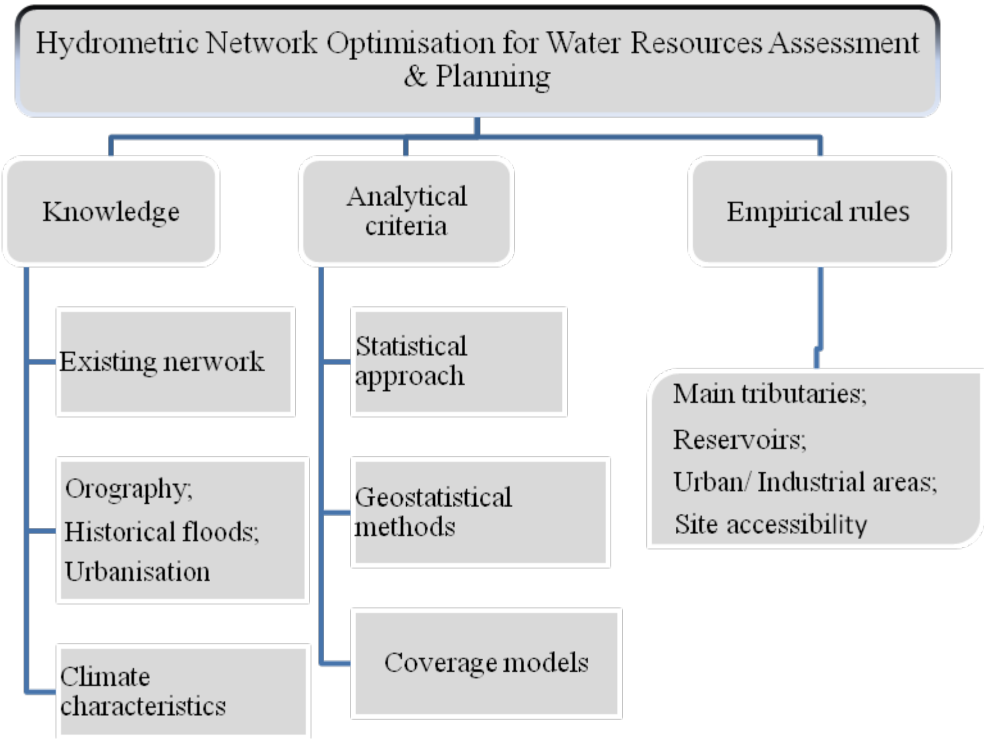
Large scale and repeat users of HIS mainly belong to various policy level and operational level government departments, financial institutions, command area development agencies, irrigation/ water resources departments, public works departments, NGOs, etc. Occasional users are of two types: those who need to find and use water in a micro-geographical area for their own use, and those who need to find and use water for commercial purposes or community activities.

Government of India (GoI) is currently implementing Hydrology Project (HP), with external support from the World Bank. Phase I of the project, termed HP I, was implemented during 1996-2003; with HP II, the second phase, currently under implementation from 2006 onwards till 2014. The project came into existence out of recognition by the GoI and the World Bank, the external aiding agency, that effective water resources planning and management demands a comprehensive HIS. The database must be readily available as a service to all users.

Looking from a techno-centric perspective, the project was not an option, but an essential requirement to avoid substantial social, economic and environmental risks that will increase with time; stemming out of designing and implementing physical water infrastructure with insufficient and unreliable hydrological data. The primary objective of the project was improvement of the country's institutional and technical capabilities to measure, collate, analyse and disseminate quantity and quality data concerning all aspects of surface and ground water resources, including climatic data.

CWPRS is one of the implementing agencies of HP. Within the overall framework of HP, CWPRS primarily performs the role of facilitator in R&D, training and activities involving special studies. Towards this end, the project provided for institutional strengthening by way of up-gradation of rating tank facility for calibration of current/ flow meters, procurement of advanced hydrometric and bathymetric equipment, R&D studies and training.

Hydrologic network:
Hydrological network includes subsystems for measuring stream flow, precipitation, groundwater, evaporation, etc.; and provides water-related data for HIS. Thus, for a river basin, the hydrometric network for measurement of stream flows forms a subsystem of the hydrometeorological network. Setting up and maintaining such a network is an evolutionary process, wherein a network is established early in the development of the geographical area. The network needs to be reviewed and upgraded periodically to arrive at the optimum network. Different approaches exist for optimisation of a real life network, as delineated below.



Approaches to network optimization

In the context of budgetary, human resources and other constraints faced by the agencies entrusted with primary collection of water data, CWPRS carried out under provisions of HP II, a study for optimisation of hydrometeorological network in the Upper Bhima basin. The study served as a pilot study, and resulted in arriving at optimum network for the basin under study [10]. The optimum raingauge network proposed was about 20 % less than the existing network of 44 stations. As regards hydrometric network of 14 stations, six were noted to be adversely affected by backwater, and needed corrective steps. Further, the study also enabled assessment of the sites in terms of information content contributed by each [11].

Modelling capabilities:
A major challenge for future in water resources sector will be development of analytical and modelling techniques, which would enable holistic approach to resource management. Advances in modelling capacities are closely associated with advances in computers, and the interaction between modellers of hydrologic systems, programmers and hardware specialists. Hydrologists make use of GIS technology to integrate various data and applications into one manageable system.

With a large number of water resources projects in different stages of planning and execution in difficult terrains such as Himalayan ranges and mountainous terrain (E.g. Tehri dam in Uttarakhand, Baglihar on Chenab river in J&K, Dibang project in Arunachal Pradesh, etc.), the need for modelling skills is all the more pronounced, especially for hazard assessment.

To usher in uniformity of approach among state and central agencies in water data dissemination, under HP II, work is under way for development of standardised hydrological design aids (HDA) using well-established, internationally acceptable methodologies. HDA aims to provide a platform for simplifying and making more accurate a range of hydrological analysis tools and associated guidance for users across India; and would facilitate and expedite hydrologic design and assessment of surface and ground water resources. CWC is the nodal agency for the initiative, and the design aids to be developed include those for: assessment of resources potential, estimation of the design flood and sedimentation rate to assess the life of a project [12].

Under provision of HP II, a generic Decision Support System (Planning) [DSS (P)] model has been developed. The model addresses five components of DSS for planning: namely surface water, resources, conjunctive use, drought, and water quality. The model, developed by DSS (P) Consultant to HP II, has been installed at the premises of relevant implementing agencies, from where the model is to be regularly used as a central hub for decision making involving data, maps and other information through the medium of internet. Some of the basins for which the DSS (P) model has been applied include: Palar basin in Karnataka, Tungabhadra reservoir command area in Andhra Pradesh, Upper Bhima in Maharashtra, Seonath river basin and Saroda command area in Chattisgarh and Mahi river basin in Gujarat.

3.2 Products and services:

Collection of hydrometeorological data using instruments, and transmitting them to wherever the data are needed for analysis and decision making, form an important component of HIS. Use of new products and services that are designed to enhance the quality and speed matters in water resources management applications. Short message service, internet, cloud computing and other future developments in these areas will be of vital interest.

Acoustic Doppler Current Profilers (ADCPs) are established tools for water management in riverine and coastal environment, which are increasingly being used in India. For the real time data acquisition system under installation by the Government of Maharashtra for Krishna and Bhima basins, ADCPs form a part of the system. Likewise, Integrated Bathymetric System for Reservoir Sedimentation Survey (IBSRSS) makes it easier to carry out hydrographic survey of reservoirs. CWPRS, over the years, has carried out hydrographic survey using IBSRSS for many reservoirs such as Gangapur, Kateri, Ooty and Satanur.

Under HP, CWPRS upgraded the Current Meter Rating Trolley (CMRT), and refurbished the rating tank facility to meet current meter calibration requirements in accordance with the relevant national/ international standards. The upgraded CMRT is equipped with instruments based on state-of-the-art technology such as variable-speed servo motor drives with programmable logic controller for precise trolley speed control in the range of 0.01 m/ s to 6.0 m/ s; and real-time data acquisition and processing system capabilities for current meter calibration. The upgraded facility conforms to calibration requirements in terms of procedure and accuracy as stipulated under ISO 3455.

3.3 Research:

For each case involving water resources development and management, the optimal solution needs to be obtained and fine–tuned, to match site–specific conditions and user's expectations through R&D. With the increasing demand on water resources, and an increased awareness of resultant environmental impact of conducting and operating physical works that alter natural flow regimes, more and more questions would routinely be raised during project formulation stages regarding the before and after comparison of proposed projects. For sustainable water resources development, topics like these, and numerous others, naturally become subjects of R&D. Moreover, the intensity of external effects in water use is greater than in any other sector of the economy; which is why water resources have very often been a publicly managed or regulated resource. For the reasons above-mentioned, in India, the magnitude of investment from the national exchequer in water resources is huge, calling for the use of best available technology to manage the investment; which translates to need for effective R&D in the water sector.

Water resources R&D falls into three broad categories: basic, specific/ applied and action research. Basic research comprises investigations or studies of specific problems, which add to the theoretical knowledge that may or may not find immediate applications, but would definitely advance technology for future applications. Basic research also provides necessary inputs for applied research on specific problems. Specific/ applied research studies are those for finding appropriate solutions to the problems confronted by engineers in the field, based on the available research knowledge.

Often, specific research is referred as applications. Applications can essentially be either `works' or 'studies' carried out for specific purposes. Works may concern hydraulic and hydro-informatics investigations and design developments carried out and implemented. These also may be related to actions such as design and implementation of decision support systems, riverine water quality monitoring, real time flood forecasting systems etc. Action research includes studies on pilot projects, field problems, and those investigations relating to model prototype conformity to put available research results, to test, in order to assess their validity for practical applications. The purpose driven study for optimisation of stream gauge and rain gauge network for Upper Bhima basin, summarised under section 3.1 above, is an example of such a study.

Holistically looking, sustainable water resources development is an integrated activity involving engineering and economic issues as well as resource policies. Water resources projects are sustainable, if water of sufficient quantity and quality is available, at acceptable prices, to meet the demands and quality standards of the population of the region now and in the future without causing the environment to deteriorate.

Sustainability must be the concern of project planner and all engineers and scientists involved in the planning process of a water resources project. However, technical skills alone are not sufficient to make a system sustainable. Sustainability also requires a willingness to go beyond the scope of standard technical solutions, for which better understanding of the interaction of the system with its surroundings and with other uses is necessary.

4. CONCLUDING REMARKS

Modern technology has contributed immensely to the sustenance of Indian population at the present level. Water, through its development, conservation, control and protection enters into infrastructure in a big way. The key to sustainable water resources development in the country is effective use of innovative techniques in the sector, which in practice, translates to larger role for R&D to find ways and means for tackling inefficiency and waste, both in delivering water-services and in responding effectively to water demand. Issues such as climate change, growing urban demand, land-use changes and environmental requirements continue to influence adversely sustainable water resources development and management. R&D provides the underpinning for use of best available technology and optimum use of water resources.

In the above context, this study has given an overview of the existing water management practices in the country, and identified the major challenges facing water resources management today. Such challenges include climate change, increased vulnerability due to extreme events, rising urban demand of water and consequential change in water dynamics, allocation problems relating to existing demands, unrestricted extraction of water resources and environmental requirements. Also elucidated is the role of hydrological services including focused R&D in resolving the varied issues.

Recent efforts in enhancing institutional capacity for decision making is elaborated in the context of implementation of World Bank aided Hydrology Project, wherein CWPRS is one of the Implementing Agencies. R&D efforts in water sector are shown to assume two major roles in furthering sustainable water resources management: i) in helping to decrease the vulnerability by furthering development and increasing adaptive capacity, and ii) by giving an option to respond to numerous contingencies that an unknown future holds.

In an information-based global economic system, all knowledge has potential economic value. However, in the modern-day information and communication technology led R&D era, universities, research centres and researchers are no longer in total control of the definition and production of knowledge; but are simply actors in a multi-sectoral social, political, scientific and technological enterprise. This augurs well for setting the ground for technical innovation in varied areas, especially water sector; where high technology is a historical necessity on account of the ever-burgeoning human population and consequential water demand.

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Dr. I D Gupta did his M.Sc in Physics from Delhi University, M.S. in Civil Engineering from University of Southern California, USA and Ph.D in Earthquake Technology from Poona University. He joined CWPRS as a Research Officer in 1979 and rose to the post of Director in August 2009. Prior to taking over as Director CWPRS, Dr. Gupta has worked in the areas of Earthquake Engineering, Vibration Technology and Structural Dynamics, with specific reference to safety of hydraulic structures. As Director CWPRS, he is responsible for overall organising and managing the studies in major areas of River Engineering, Coastal Engineering, Reservoir and Appurtenant Structures, etc. Dr. Gupta is representing in many Technical Committees in the areas of specialisation of CWPRS. He is the Chairman of Sub-Committee-1 on “Hydrometry”, of Water Resources Division of BIS and also the Chairman of Sub-Committee-6 on “Sediment Transport” under ISO-TC:113 on “Hydrometry”.