Creativity in Water Management: The R&D Perspective

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ABSTRACT

Close and vital links exist between creativity, innovation, and research and development (R&D) in virtually any area, with water management being no exception. Creativity relies on intense cognitive processes of recognition, reasoning and understanding; which leads to innovation. Innovation process can basically be visualised as a linear chain that begins with basic research; moves on to strategic and/ or applied research, and finally to product/ process development and implementation. For a sector, the underlying information system, coupled with R&D, provides the underpinning for creativity and technical innovation. In reality, however, creation and application of new knowledge is an interactive process with multiple feedback loops. In the context of water management, the hydrological information system (HIS) for decision-making comprises data collection and storage system, data communication system, data transformation system that produces information, and information communication system. Such an HIS, in its entirety, leads to inputs to informed decision making. This interactive process is fuelled by the key factor of information; which decides the creativeness, innovativeness, and above all the quality of decisions taken by those who are entrusted with the planning, development and management of the country's water resources. Thus, effective use of HIS can be identified to be the underpinning for creativity in water management. In this context, this study examines the role of HIS and water resources R&D in creativity and innovation in water management. With the increasing demand on water resources, and increased awareness of resultant environmental impact of constructing and operating civil works that alter natural flow regimes, more and more questions are routinely raised during project formulation stages regarding the before and after comparison of proposed projects. Topics like these, and numerous others, are subjects of R&D. The challenge for a developing country like India, in enhancing creativity in water management, is to reinforce its human and institutional capabilities such that all sectors, firms and individuals have access to knowledge as and when needed. For a better part of the twenty-first century, the twin concepts of knowledge and research have enjoyed broad and positive consensus. Accumulated knowledge served as compelling witness to the power of science to produce immense benefits to mankind. However, within the last decade, with globalisation taking centre-stage, the fervent praising of knowledge and science has lessened. The study indicates that R&D institutions face a continuing need to re-orient themselves to plan strategies for future in relation to not only what it used to do in the past, but also in relation to what others in allied fields the world over are likely to do in the future.

1.0 INTRODUCTION

Modern technology has contributed immensely to the provision of water to the burgeoning population of the country at the current level of about 124 crore; despite importunate issues - ranging from land-use changes, unrestricted extractions, climate change, growing urban demand and environmental requirements - continuing to influence adversely sustainable water resources management. Further, growing population and expanding economy are resulting in increased competition for water to meet household, municipal, agricultural and industrial needs. Simultaneously, laws and regulations, oriented towards keeping water in rivers so as to meet environmental and recreational objectives are on the rise. The primary way to cope with water issues is to increase manifold technical innovation to facilitate optimum utilisation of scarce resources. This, in practice, trickles down to increased R&D efforts in the water sector.

For the modern Indian society, which is getting increasingly urbanised, the generic term water, for all practical purposes, means clean water for domestic use and treatment of waste water and sewage; and water for irrigation for agricultural needs and for industrial needs. As long as there is no acute shortage or deficiencies in the provision, water is taken for granted by the society.

The lay society refuses to view water as a critical resource that has got a financial value attached to it. The question of whether water is a basic human right, or a commodity in need of a market, is not easily answerable; and is a debate that is political, and emotionally charged. Of late, fresh water is also increasingly assuming the role of a global resource, driven by international trade in water-intensive commodities such as crop, livestock products, natural fibres and bio-energy; because of which water is also getting spatially disconnected from the consumers. Economists and planners contend that water is the same as food, a staple of life, whose price should be controlled by market forces; while others believe water is like air: abundant, open to abuse and free to all. The truth is that water is somewhere between the two; free, but costly to distribute and process. Experts point out that though the water is free, there are many opportunity costs associated with its procurement. Villagers can spend half a day traveling to a standpipe, waiting in line, and transporting the water back to their homes. Some of them need to do this every day. In the democratic set up of our country, provision of water infrastructure and its upkeep are traditionally considered to be the responsibility of the state; with the general tendency being to blame the government for all the ills connected with supply and provision of water.

Water infrastructure is three times more expensive to build and maintain than electricity infrastructure. Much of it runs underground, out of sight of the average consumer. But neglecting it can be even more costly. It is estimated that in many cities, at least 20 percent of water is lost to leaks. Building and repairing water infrastructure is disruptive, inconvenient and time-consuming. But it needs to get done. There are immense opportunities to not just fix or rebuild existing infrastructure, but to do it better and smarter, adding intelligence and instrumentation into the systems.

A perception exists within the water sector to the effect that technology does not necessarily have to be cutting edge in the sector; and needs only be fit for the purpose in hand. As such, water has been a relatively low technology industry. With water becoming scarcer, per capita consumption rising with steadily improving living standards, quality standards rising, existing water infrastructure deteriorating and the exigency to reduce the environmental impact of infrastructure growing, it is imperative that the pace of technology and innovation must grow for the sector. Water sector needs to innovate to deliver reliable water supplies efficiently at higher quality, with lower environmental impact. Where R&D and innovation will lead to better operational or capital investments or service efficiencies, or where there are new challenges to be addressed and yesterday's solutions are not fit for purpose, a deliberate case needs to be made for the same. However, if the investment is simply technology for its own sake, or is not cost-efficient over the life cycle of the investment, or if the innovation is seen as a one-off rather than a component of sustained investment plan, then the case is weak.

As indicated above, the governmental regime that exists to a large extent in the country in the water sector has a structural bias against R&D solutions; and provides insufficient rewards for innovative solutions. Much of the water technology that municipal, panchayat and other local agencies currently use is the product of engineering innovations from the mid twentieth century. Though it is a good legacy, nurturing of the technological content by way of keeping up the innovations in the sector is a prime necessity; with water being one of the most stressed resources in India. The existing infrastructure in many cities of the country traditionally focuses on managing their assets to maintain serviceability and reduce costs, rather than on service improvement through technical innovation. The focus has traditionally been on delivering the necessary investment to meet regulatory environmental standards, than to deliver operational efficiencies. This has meant little stimulus for the sector to be less risk-averse in terms of adopting new technology. Changes are needed to the regulatory regime to incentivise investment in R&D and innovation. In general, it can be said that innovation within the water industry is fragmented, with sub-optimal sharing of information, which risks the same problem being approached in different ways by different agencies, with little or no cross-over.

Of added significance is the multiplicity of issues of today's water management such as climate change, land-use changes, growing urban demand and environmental requirements; which continue to influence adversely sustainable water resources development and management.There is an urgent need for changes in the application of technology to address such issues, and enable further improvements to the efficiency of operations within the water sector to be made. The current levels of incremental technology improvement may not be enough, particularly in terms of addressing the most pressing challenges. One essential requirement is to have a clearer understanding of how the system is operating by incorporating modern measurement and control systems as a pre-requisite as the infrastructure is upgraded and expanded. An old dictum reminds that what is not measured cannot be controlled. The scope for automated or computer-based controls that can optimise system performance is immense. The main caveat is that agencies should put in place mechanism for measurement of what is garnered, and what is delivered.

Research and development (R&D), often referred as the engine of prosperity, provides the underpinning for use of the best available technology in water sector, and optimal 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. In this context, this study explores the linkages between creativity, innovation and R&D; and brings out on the role of hydrological services and focused R&D in resolving varied water management issues in the country.

2.0 CREATIVITY, INNOVATION AND R&D

The concepts of change, creativity, innovation and knowledge management have never been more topical, especially given the clamour for efficient and relatively cheap provision of resources such as water and power. Customers are more demanding, and the product cycle of technological innovations is becoming shorter and shorter. This is all the more relevant since it is universally accepted now that knowledge is the prime driver of economic activity; with increased reliance on knowledge and innovation in the creation of products and services.

Close and vital links exist between creativity, innovation, and R&D in virtually any area, with water management being no exception. Creativity relies on intense cognitive processes of recognition, reasoning and understanding; which leads to innovation. Innovation process can be visualised as a linear chain that begins with basic research; moves on to strategic/ applied research and finally to product/ process development and implementation.

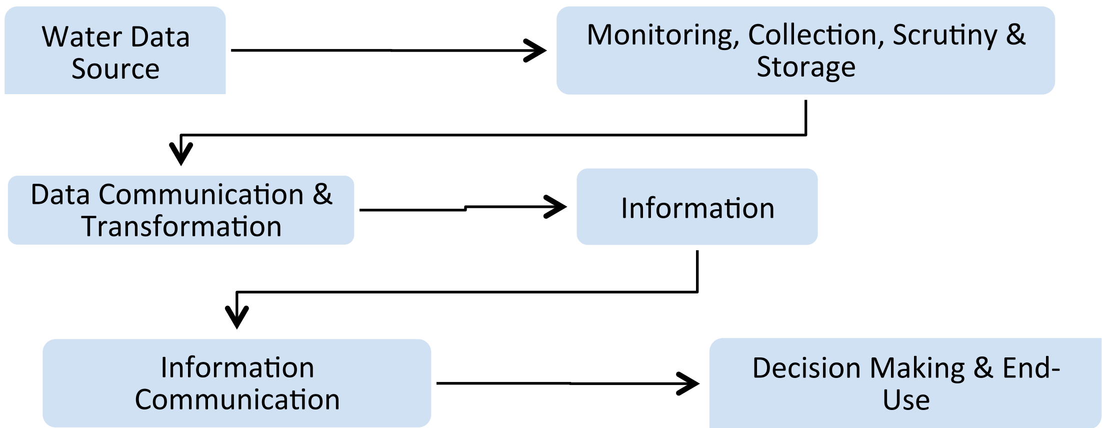
Creativity can be viewed as the ability to transcend traditional ideas, rules, patterns, relationships or the like, and to create a meaningful new idea, forms, methods, interpretation, etc. The underlying information system, coupled with R&D, provides the underpinning for creativity and technical innovation. In reality, however, creation and application of new knowledge is an interactive process with multiple feedback loops. Thus, when a team comprising, say hydrologists and programmers, write a code for a Decision Support System (DSS) to manage the available water resources of a reservoir system, creativity is at work. If the DSS helps in efficient, optimum use of the resources, with say, additionally helping the flood management; then the community concerned has benefitted from the creative output of the team concerned. Closely linked is the concept of innovation, which in effect is the use of new technological and market knowledge to offer new products and services that the customers will want. Typically, the cost for the new product/ service is lower, its attributes are improved, now has newer attributes it never had or it never existed in that market place before. Normally, lower cost means more profit for the firm that markets it. Further, better or new attributes command a premium for the product for the given cost, which means more profits.

All innovations are new; with variations existing in the degree of newness. Variations can be incremental, involving small steps, something that is a minor improvement to an existing solution; or radical, which takes big steps, creating major improvements that are often much different from existing solutions. Revolutionary innovations happen when a group of innovations together cause a big, far reaching impact. Focus of innovations also varies: it can involve new products as also new characteristics of old products. The process that makes the product may be much the same, but the product may change incrementally or radically. Innovative processes involve new ways of doing things. The product may be the same, but the way of producing is new, better, much more efficient and reliable.

3.0 HYDROLOGICAL INFORMATION SYSTEM

The value of information for sustainable water resources development is self-evident. Information can be viewed as a product of basic data, operated upon by mathematical, statistical, hydraulic, hydrological and other optimisation models. Specific information to be produced would depend on factors such as the immediate need, recognition of the problem, and its subsequent solution using the relevant model(s). If the database is well designed and the model(s) 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 monitoring, collection and storage 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 are raw facts representing characteristics of natural phenomena or events - say flood levels, 24-hr recorded rainfall at a location, spot temperature, maximum/ minmum temperature recorded in a day, etc. - made up of numbers, text, images and the like. Information is data that have been processed to make it more meaningful and useful. This processing, or transformation is in practice done by models, which can range from simple mathematical/ statistical models, hydrologic design aids, nomograms, decision support system (DSS) models, etc. 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. It is widely recognised that, over a period of time, the general populace is capable of utilising efficiently and effectively data/ information/ knowledge, available amongst all the subjects, since it is basically a process of discovery. This aspect introduces a collective element in the complex process; and enhances the creativity in related services, products and processes.

Water data 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. To exemplify, a hydraulic research station like the Central Water and Power Research Station (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; whereas state Water Resources Departments take a dual role of collector of data as also user of the same in the day-to-day planning and management of water resources. Large scale and repeat users of HIS mainly belong to various policy/ operational level government departments, financial institutions, command area development agencies, irrigation/ water resources departments, public works departments, non-governmental organisations (NGOs), etc. Occasional users are primarily 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.

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 the information communication technology (ICT) field.

During 1996-2003, the Government of India implemented Phase I of the Hydrology Project (HP) as a six-year project, with external assistance from the World Bank. Under HP, HIS under the purview of the participating agencies has been strengthened as a distributed system, comprising interrelated autonomous components. The participating agencies included the central agencies of Central Water Commission (CWC), CWPRS, National Institute of Hydrology (NIH), Central Ground Water Board (CGWB) and IMD; and the nine states of Andhra Pradesh, Chhattisgarh, Gujarat, Kerala, Karnataka, Madhya Pradesh, Maharashtra, Orissa and Tamil Nadu. Hydrology Data Users Groups (HDUGs) were also established under the aegis of HP, which is playing a pivotal role in stimulating demand from sophisticated data-users, and has grown to be the steering element in furthering HIS development.

The second phase of HP, termed HP II, commenced in May 2000; and would run up to May 2014. The project aims to extend and promote the sustained and effective use of HIS by all potential users concerned with water resources planning and management, both public and private, thereby contributing to improved productivity and cost-effectiveness of water-related investments of the implementing agencies. A focus area is to use HIS in planning and management of water resources; involving development of hydrological design aids (HDAs) and decision support system (DSS) tools. Some of the HDAs identified to be developed under the provisions of HP II that are relevant to flood hazard assessment are: depth-duration-frequency curves for short-duration rainfall, probable maximum precipitation/ probable maximum flood estimation using available autographic rain gauge data and estimation of flood frequency for different return periods.

Looking from a techno-centric perspective, the World Bank aided Hydrology 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.

4.0 ENHANCING CREATIVITY IN WATER MANAGEMENT

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.

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 hydroinformatics 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.

Globalisation and localisation are two important forces shaping economic development in the twenty-first century. The challenge for a developing country like India, towards enhancing creativity in water management, is to reinforce its human and institutional capabilities such that all sectors, firms and individuals have access to knowledge as and when needed. Since private sector typically under-invests in R&D, it is imperative that governments strengthen research capacity, setting clearer research priorities and establishing better systems for channelizing public research funding. The wherewithal to involve a range of people and approaches that need to adapt and change over time to meet different contextual requirements and changing environment are crucial in implementing the research schemes funded by the government. In addition to direct benefits, by financing R&D, the government is also educating its workforce with the knowledge and skills that are needed to innovate. As is the norm today, much of the research that is conducted is largely done in government laboratories, universities, within firms, or at consortia made up of a combination of all the three. Government financing of R&D is also not always direct. Some agencies receive indirect financing through tax breaks, government subsidies, and the like.

R&D institutions form a repository of domain knowledge in the area of specialisation. As such, it is crucial that R&D institutions are reformed, and made more responsive to the market. Reform measures often employed include corporatising institutes, improving the pay and recognition of researchers and giving direct incentives for placing research contacts with R&D institutes.

The strategy of R&D institutions may need to be based, from now on on the assumption of shrinking staff strength partly due to cost-cuts and partly due to out-sourcing of even technological jobs to increase viability. In this era of fast reducing workforce in every sphere, in knowledge-based R&D jobs, with age being less of a disadvantage, making use of the talents of personnel beyond current retirement age, may also need to be explored. Key R&D infrastructure needs to be re-directed for result-oriented, market-based mode of operation, which will increase productivity.

Public private partnership (PPP) in water sector is also seeing increasing activity; especially in the water distribution area. There is immense scope for PPP under water supply, sewage treatment, and related areas; which would infuse new talent and technology into the sector. Successful implementation of PPP can potentially pave the way for infusion of much needed additional from non-governmental sources, and proven technologies in the water and waste management sector. Nagpur, Salt Lake (Kolkata), Khandwa, and Shivpuri towns are certain examples where PPP route is being attempted for improving water infrastructure in them.

If there is an endeavour whose fruits should be freely available, that endeavour is publicly financed science and technology. Presently, the tendency is to publish research findings in peer-reviewed journals that have got restricted access. One reason for this is the prohibitive cost of technical journals. Only few libraries with extensive financial resources can afford a major chunk of the large number of water research journals published in the country and abroad. Ideally, the general public who wish to should be able to read at least all public-funded water research results without incurring substantial expenses. Technology advances through cross-fertilisation between projects, products and processes. Open-access publishing of public funded water research should go a long way in dispersing innovative ideas far and wide. Uploading reports/ papers/ documents into public archives would need governmental support, active backing and encouragement for obvious reasons. This is all the more relevant, especially in the context of the movement world over for open-access publishing in science and technology.

Sustained scientific and technological initiatives are needed in the hydrological services regime. Some of the major components of hydrological regime include: hydrological networks as also diverse products and services. Hydrological network includes subsystems for measuring streamflows, precipitation, groundwater, evaporation, etc.; and provides water-related data for HIS. Thus, for a river basin, the hydrometric network for measurement of streamflows 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. The author of this study was associated with a study of the nature recently. Summary results of the study are given below to show what can be achieved by such endeavours.

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. The optimum rain gauge network proposed was about 20 percent 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.

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.

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.

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.

Since many environmental and resource-sharing problems extend beyond regional and national boundaries, the regional/ local governments/ agencies are creating institutional structures that are able to respond to trans-boundary issues. Efforts made for interlinking of Indian rivers, as also works of Water Disputes Tribunals (WDTs) set up at different points of time, are examples in this direction. The National Water Policy, revised from time-to-time, gives guidelines in this direction.

5.0 EPILOGUE

Water and its management are major issues today, having greater impact on our lives than ever before. Growing population and expanding economy are resulting in increased competition for water to meet household, municipal, agricultural and industrial needs. In the context of today’s increased emphasis on innovation, creativity, collaboration and teamwork, the challenge for a developing country like India, towards enhancing creativity in water management, is to reinforce its human and institutional capabilities such that all sectors, firms and individuals have access to knowledge on as and when needed. The hydrological information system of the country, of late strengthened with much technological inputs through implementation of the ongoing World Bank funded Hydrology Project, forms the backbone of water management of the country; providing reliable data for long-term planning, design and management of resources and water use systems, and for research activities in related areas. As is self-evident, 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.

The general public is capable of utilising data/ information/ knowledge, available amongst all the subjects, due to the fact that it is basically a process of discovery. This aspect introduces a collective element in the processes; which enhances the creativity in related products and processes. 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. In all such pursuits, the relevant information system provides the underpinning for infusing creative and innovative solutions to water management issues.

For a better part of the twenty-first century, the twin concepts of knowledge and research have enjoyed broad and positive consensus. Accumulated knowledge served as compelling witness to the power of science to produce immense benefits to mankind. However, within the last decade, with globalisation taking centre-stage, the incessant praising of knowledge and science has begun to thin. The need of the hour is an in-built culture in the water industry which places a high value on developing, incorporating and sharing the latest technology, underpinned by a strong research base.

The study points to the fact that especially R&D institutions face a continuing need to re-orient themselves to plan strategies for future in relation to not only what it used to do in the past, but also in relation to what others in allied fields the world over are likely to do in the future.

There exists a common perception among society that government agencies, including R&D organisations, have not delivered what was expected of them. The GoI has implemented a new performance monitoring and evaluation system for Departments with effect from Sep 2009. The system is designed to rectify certain limitations of the current system of accountability for results in government, and includes for each department/ ministry results framework document that provides a summary of the most important results expected to achieve during the financial year. This document serves the purposes of moving the focus of the department from process-orientation to results-orientation, and provides an objective and fair basis to evaluate department's overall performance at the end of the year. Included in the document are: vision, mission, objectives and functions of the organisation; interse priorities among key objectives, success indicators and targets; trend values of the success indicators; description and definition of success indicators and proposed measurement methodology; and specific performance requirements from other departments that are critical for delivering agreed results. Such initiatives have helped in ensuring accountability of public funded R&D organisations.

R&D institutions, being repositories of domain knowledge in the specific areas of specialisation, it is crucial that they are reformed, and made responsive to the market. Reform measures employed can include corporatising institutes, improving the pay and recognition of researchers and giving direct incentives for placing research contacts with R&D institutes. Further, in this era of fast reducing workforce in every sphere, in knowledge-based R&D jobs, with age being less of a disadvantage, making use of the talents of personnel beyond current retirement age, also needs to be explored. Key R&D infrastructure needs to be re-directed for result-oriented, market-based mode of operation, which will increase productivity. Open-access publishing of papers, reports and other documents that emanate from public funded water research needs to be promoted to ensure that cross-fertilisation of technological endeavours trickles down to the general public.

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