INDIA NEEDS INNOVATION IN HYDROLOGICAL MEASUREMENTS AND INSTRUMENTATION: A CASE FOR PPP

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ABSTRACT

Knowledge of water availability and its distribution and variability in space and time is an essential prerequisite for a number of activities ranging from the forecasting of floods to the management of water resources and assessment of the potential impact of climate change. The collection and continuous supply of reliable and timely data, as well as the establishment and maintenance of historical data series, are basic requirements for acquiring information for planning and management purposes. Hydrological instrumentation plays an important role in the hydrologic research and development.

It is well recognized that there is an urgent need of strengthening the hydrological and meteorological data collection network in the country. This concurrently requires skilled manpower to install, operate, repair/maintain the advanced instruments. Education and training, coupled with human resource development policies for regular updates through refresher courses, etc. will be of utmost importance to the success of hydrological data monitoring efforts. The Planning Commission recently constituted a working group to assess the present system of collection and dissemination of water related data and to suggest improvements. The group has recommended a massive strengthening of the existing data collection network by replacement of obsolete instruments and installation of advanced instruments.

A whole new mindset and innovation will be needed to identify and solve future water-related problems, which will require substantial attention and additional investments to capacity building. It is hightime that we take cognizance of this lacuna in our data collection efforts and take corrective steps by addressing the issues of shortage of skilled manpower and lack of testing/repair/ maintenance facility for the new-age instrumentation. This is a very good case for PPP in water management efforts, where industry can have a well defined role not only in developing/providing the required instrumentation but also in establishing and operating the repair and maintenance facilities across the country. The paper summarises the various issues of hydrological measurements and instrumentation, and discusses the innovations needed, including the potential of PPP for this activity.

INTRODUCTION

In order to sustain the water needs of different sectors, the country needs to focus on the efficient use of all water sources (groundwater, surface water and rainfall) and on water allocation strategies that maximize the economic and social returns to limited water resources, and at the same time enhance the water productivity of all sectors. Technological innovations are needed to ensure future water supplies (UNESCO, 2009), and to ensure that the country's spending on water management efforts is utilized in a cost-effective manner. Paucity of reliable data on water quantity and quality as well as on water use, wastewater recycling and reuse, economics of operations, environmental impact, is often considered to be a limiting factor in successful implementation of water management plan (Biswas and Seetharam, 2008). Without good data it is not possible to adequately monitor progress or performance of policies, programmes or projects. To ensure efficient water planning and management in the future, data availability (at desired spatial and temporal scales), its quality and access need to be improved significantly.

Whether it be for meteorological, hydrological, oceanographic or climatological studies or for any other activity relating to the natural environment, measurements are vital. Knowledge of what has happened in the past and of the present situation, and an understanding of the processes involved, can only be arrived at if measurements are made. Such knowledge is also a prerequisite of any attempt to predict what might happen in the future and subsequently to check whether the predictions are correct. Without data, none of these activities is possible. Measurements are the backbone of them all.

In large parts of the world, including India, the collection of water-related data has been in serious decline in recent years. When stations malfunction, they are closed because there are no resources for maintenance, repair or spare parts. Essential activities such as station calibration are neglected, because of a lack of money for field travel. Computer archives are maintained on obsolete equipment or have never existed, and paper records are fast deteriorating. The net result is that the records have long gaps and are of unknown quality. This drastically reduces their value for engineering design, assessment of trends in the resource, or informed planning and resource management.

HYDRO-METEOROLOGIC DATA NEEDS

Knowledge of water availability and its distribution and variability in space and time is an essential prerequisite for a number of activities ranging from the forecasting of floods to the management of water resources and assessment of the potential impact of climate change. The collection and continuous supply of reliable and timely data, as well as the establishment and maintenance of historical data series, are basic requirements for acquiring information for planning and management purposes.

A strong hydro-meteorological database is crucial for understanding the natural resources and processes operating in a watershed, e.g. erosion, landslides, soil loss, degradation, water availability for domestic and irrigation purposes. This also helps, for example, in answering the following queries:

- What is the spatial and temporal pattern of rainfall?
- How are the streamflows varying on annual, seasonal or monthly basis?
- What is the expected peak flow to design conservation structures?
- What does the water balance look like?
- What is the groundwater potential, and where are the recharge areas?
- What is the quality of water?
- Which are the suitable sites for construction of water conservation structures?

Reliability and consistency of measured data are essential if the hydrological modeling studies are to best benefit from the technological advancement (WMO, 1994). Sophistication in modeling and analysis notwithstanding, the results could only be as good as the data. The model may be exact and analytical procedure accurate, but the results cannot be relied upon if the data is inadequate and/or of poor quality.

There is an increasing need to expand the number of hydrologic parameters to be sensed, improve the reliability of existing sensors, and improve the efficiency of the stations that provide data to the agencies involved in the operational hydrology (Dozier, 1992). Typical application of instruments in the hydro-meteorological monitoring programmes may be found in Hofer (1998), Paige et al. (2008).

WATER RESOURCES MONITORING IN INDIA

The current institutional arrangement for managing water resources in India involves various government agencies. At the central level, the Ministry of Water Resources (MoWR) is responsible for developing, conserving and managing water as a national resource covering areas as diverse as irrigation, ground water exploitation, drainage and flood control. The Ministry of Environment and Forests (MoEF) is the nodal agency for water quality and environmental matters. Water supply in urban and rural areas is coordinated by the Ministries of Urban Affairs and Drinking Water and Sanitation, respectively. Besides, water is also a subject of several other ministries and departments such as the Ministry of Agriculture, Science and Technology, Power, Health and Family welfare, Surface Transport and the Inland Waterways Authority.

State governments implement many programmes for watershed development, soil conservation, irrigation, flood control, drinking water & sanitation, etc. There are a number of externally aided projects assisted by the World Bank, EEC, KFW, DFID, DANIDA, SDC and ODA. Funds are also provided by the National Bank for Agriculture and Rural Development, commercial banks and cooperative societies for developing watersheds. Besides the above organizations involved in operational hydrology and related measurements, there are many R&D and academic organizations in the country that are using hydro-meteorological instruments for specific research studies or projects.

During the last two decades, a number of studies/projects have been taken up, both at the government and non-government levels, for the development of natural resources, including soil and water resources. A variety of automated instruments have been installed under these projects (e.g. World Bank aided Hydrology Project, Indo German Bilateral Project) for monitoring of hydro-meteorological parameters. Besides these installations, the regular monitoring networks of national agencies like India Meteorological Department (IMD), Central Water Commission (CWC), Central Ground Water Board (CGWB), Central Pollution Control Board (CPCB), and many State organizations, are in operation for collection of hydro-meteorological data. As such, thousands of installations of hydro-meteorological instruments are presently available in the country (Table 1).

Table 1. Existing monitoring network of major national organizations

Parameter/Instrument	**Agency**	**No.of Installations**
Rain Gauges Snow Gauges	India Met. Dept. Other organizations India Met. Dept.	559 8579 21
Hydromet Observatories Agro-met Observatories Evaporation stations PET stations Lysimeters Meteorological profilers (towers)	India Met. Dept.	2500 219 238 144 42 40
Hydrological stations (discharge, stage, sediment, water quality) Flood monitoring stations (telemetry) Flood forecasting stations	Central Water Commission	878 410 175
Groundwater Level Recording stations	Central Ground Water Board States	DWLR- 1200 Piezometers- 3500 GWO wells- 15000 GWO wells- 40000
Water Quality stations	Central Water Commission Central Pollution Control Board	371 1700 (Rivers- 980 Lakes- 117 GW- 490 Ponds- 44)

HYDROLOGIC INSTRUMENTATION

Measurement of the hydromet variables dates back to the 17th century, when the first mercury barometer was made. Systematic recordings of rain, wind speed and sunshine started in the 19th century. In the last three decades, owing to developments in microelectronics and micro-controller based data loggers, new instruments have become available that greatly enhance our ability to measure the natural environment. Data loggers with low power consumption and large memory capacity have made possible the instruments to operate remotely and unattended. Sensors for this application, similar to other environmental instruments, are based on proven technologies, e.g. electromagnetic, ultrasonic, Doppler, Time Domain Reflectometry (TDR), pressure sensors, Hall-effect, reed-switch, potentiometer, capacitance, resistance, optical shaft-encoder, load-cell.

We are in an era where both types of instruments (old and new-generation) are in use, and both are important, although the change to the new is happening gradually. A serious limitation of the old instruments is that, being manual and mechanical, they need operators and this restricts their use to those parts of the land that are inhabited. Most mountainous, desert, polar and forested areas are, as a consequence, almost completely blank on the data map (Strangeways, 2000). In contrast, the new instruments need operators only once every few months, or even less frequently, and so can be deployed at remoter sites. It is also possible to use telemetry communication systems with these new instruments for transmission and storage of data from remote sites. The resolution, accuracy and frequency of measurement have greatly improved with the new-generation instruments.

EMERGING ISSUES AND NEEDS IN INDIAN CONTEXT

Strengthening of Monitoring Networks

A number of reports and papers have indicated the need for monitoring systems, including data archives, for water resources assessment and management. These have also identified the importance of communicating information on water to decision-makers, researchers and to the general public (Rodda, et al., 1993). It is universally recognised that there are various limitations in employing skilled manpower for regular monitoring of hydrological data, especially from remote and inaccessible sites and during times when the need is utmost (e.g., during rain-storms, floods). To correct this shortfall of data, there is now an urgent need for a network of stations integrating meteorology with hydrology and the other environmental sciences (Strangeways, 1995).

Major organisations responsible for hydrologic data collection in the country, as mentioned in the preceding sections, and many other Central and State Agencies/Organisations involved in hydrologic data collection, lack in consistency and compatibility of data collected. Mostly, all these organisations are monitoring the hydrologic data on river basin basis. India, with its vast land and water resources, at present is generally lacking in systematic data collection at watershed scales. All these watershed development programmes need hydro-meteorological monitoring to analyse the impact of these programmes on natural resources.

The potential of hydro-meteorological instrumentation business in the country can be judged from the number of instruments required for different measurements under each region (Table 2). Comparing with the existing instrument installations in the country (Table 1), it is clear that a wide gap exists requiring many new installations and upgradation of the existing ones.

Table 2. Potential network density in Agro-Ecological Regions (AER)
(Based on standard norms)

Ecosystem (Sehgal et al., 1992)	**Area ($x10^3$ km^2)**	**No. of AER**	**No. of Raingauge stations**	**No. of Hydometric stations**	**No. of Groundwater stations**
Arid	520	03	52-347	26-104	2000-5200
Semi-arid	1164	05	1293-1940	466-1164	4477-11640
Sub-humid	1016	06	4064-10160	1016-3387	3908-10160
Humid-Perhumid	323	03	1292-3230	323-1077	1242-3230
Coastal	196	02	218-327	78-196	754-1960
Island	8	01	320	27-57	31-80
TOTAL	**3227**	**20**	**7239-16324**	**1936-5985**	**12412-32270**

Realizing the importance of reliable data in water resource planning and management, the Planning Commission recently constituted a working group to assess the present system of collection and dissemination of water related data and to suggest improvements. The group has recommended a massive strengthening of the existing data collection network by replacement of obsolete instruments and installation of advanced instruments (GoI, 2011- compiled in Table 3). The report also emphasizes the dire need of skilled manpower for effective use as well as operation & maintenance of such advanced instrumentation.

Automation of Instruments

In order to improve the quantity as well as quality of the hydrological data collected in field, the modernization and automation of data collection networks is very much a desired step. Deficiencies in the manual data collection have to be overcome by the automation of instruments. This is of special importance in developing country like ours where the 'traditional' data collection techniques face problems due to manpower availability, and with additional requirement of data from areas hitherto not covered earlier (including remote areas).

Advanced instruments have found limited access in the Indian market except in cases where projects with foreign funding are executed with technical support of the foreign instrumentation experts. Few such attempts were made in projects like World Bank aided Hydrology Project, IGBP, Yamuna Flood Forecasting System by CWC. Unfortunately, the advances and modernization of hydrological instruments in India has been caught in a vicious circle of demand and supply, i.e. since there is no predictable (reported) demand, there is no indigenous supply.

Table 3. Recommended monitoring network under 12th Five-year Plan

Parameter/Instrument	**Agency**	**No. of Installations**
Automated rain gauges Automated Weather Stations Doppler Weather Radar	India Met. Dept. States India Met. Dept. India Met. Dept.	3350 40000 950 55
Lysimeters Soil moisture stations	India Met. Dept.	130 620
Hydrological stations	Central Water Commission	1917 (i/c 810 stations with sediment & water quality)
Groundwater Level Recording stations	Central Ground Water Board	DWLR (telemetry)-10000 GWO wells- 50000
Water Quality labs	Central Water Commission	810

Testing and Calibration

All instruments need to be periodically inspected and calibrated for ensuring accuracy. Systematic testing and calibration system should be evolved and adequate number of calibration centers set up for this purpose. The calibration centers should maintain calibration standards apart from having testing and calibration facilities.

Maintenance

Robustness, simplicity of operation and maintenance are important since most hydromet instruments are in continuous use under harsh field conditions, and may be located far away from advanced repair facilities. In many instances the data collection efforts have failed because insufficient attention was paid to the logistics and the cost of maintenance. It is often observed that adequate funds are not earmarked for maintenance of instruments while preparing the budget for monitoring networks, and the natural victim of this lapse is the data collection effort. The maintenance of instruments not only requires adequate funds but also trained manpower.

Capacity Building Needs

It is well recognized that there is an urgent need of strengthening the hydrological and meteorological data collection network in the country. This concurrently requires skilled manpower to install, operate, repair/maintain the advanced instruments. This also requires a general awareness among the actual users of such instruments about the latest developments in the field of hydrological instrumentation. This could be achieved through a forum where field hydrologists and technicians can interact with the manufacturers/ vendors of field instruments.

Education and training, coupled with human resource development policies for regular updates through refresher courses, etc. will be of utmost importance to the success of hydrological data monitoring efforts. But the country presently lacks on availability of dedicated academic curriculum through which professionals specifically trained in 'technology for water management' are produced. Although India is claimed to have a huge workforce of engineers (mostly with civil, agricultural or environmental engineering qualifications) dealing with water resources, technology for water management requires skills from other disciplines as well. Expertise in the subject areas of electronics and instrumentation, mechanical engineering, chemical engineering, chemistry, biotechnology and nanotechnology, ecology, earth sciences, science communication, management (including enterprise management), economics, and social sciences is equally important in dealing with the subject of technology application (and commercialization, which is vital for wide scale dissemination of technologies and sustainability of efforts) for water management. It is hightime that a PG course on Technology for Water Management should be designed with appropriate curriculum, to be run at about 5-6 academic/R&D institutions in association/collaboration with industry partners.

INNOVATION THROUGH PPP ROUTE

The main reason behind failure of sustenance of instrumentation deployment under any major projects has been the lack of skilled (and dedicated) manpower in the State and (even) Central Govt. organizations. We don't have a cadre of professionals who specialize in instrumentation for hydro-meteorological needs. All these organizations deploy poorly-skilled (with non-instrumentation qualifications) and often unwilling engineers/technicians for such jobs.

It is hightime that we take cognizance of this lacuna in our data collection efforts and take corrective steps by addressing the issues of shortage of skilled manpower and lack of testing/repair/ maintenance facility for the new-age instrumentation (Goyal, 2011). This is a very good case for PPP in water management efforts, where industry can have a well defined role not only in developing/providing the required instrumentation but also in establishing and operating the repair and maintenance facilities across the country. How we achieve and deliver this objective for social and economic good has been the focus of this concept, which is gaining momentum within the government during the 12^{th} Five-Year Plan. Salient features of the proposed PPP approach are briefly discussed next.

Potential Suggested Activities

1. Development of field instruments

   E.g., Rain gauges, AWS, soil moisture sensors, evapo-transpiration sensors, ground water level recorders, in-situ permeameters, infiltrometers, stage recorders, stream velocity meters, water quality probes.
2. Installation, operation & maintenance of field instruments
3. Development and/or maintenance of lab instruments

   E.g., Pressure plate apparatus, lab permeameters, tensiometers, Ion chromatographs, Gas chromatographs, Atomic absorption spectrometers, TOC analyzer, Flow injection analyzers, Flame photometers, environmental chambers, Alpha spectrometers, Gamma-ray spectrometers, Liquid scintillation counters.
4. Creation of testing and calibration facility for field instruments
5. Creation of live demonstration facilities at field sites
6. Data collection and database creation

7. Creation of training facility for lab and field technicians (certificate and refresher courses)
8. Organization of periodic interactions with field engineers/ scientists and technicians to facilitate adoption of new developments in operational practice.

The basic aim of a PPP should be to provide products/services that are more economical, qualitatively better and are convenient.

i. Users of the outcome of the PPP approach

1. Government organizations (meteorology, drinking water, sanitation, irrigation, environment and pollution control, agriculture, rural development, disaster management, planning, project funding)
2. Academic and research institutions
3. PRIs and NGOs
4. User industries (hydropower, farming, horticulture, aquaculture, construction, insurance companies, aviation, transportation, wastewater treatment, rainwater harvesting, drainage utilities, banks, microfinance)

ii. Stakeholders of the research

1. Government organizations- policy and planning; demand assessment; quality control; training and capacity building of users; training of technicians; dissemination of user-relevant data and products; monitoring and evaluation
2. Private industry partners- development, installation, operation & maintenance of instrument; testing and calibration facilities; data collection; demonstration facilities; training facilities

iii. Attractiveness of the benefits accruing to the PPP stakeholders

1. Government organizations- timely availability of quality data at desired spatial and temporal scales; improvement in research (modelling) efficiency; gain in efficiency and delivery; low capital investment; skill enhancement of field staff
2. Private industry partners- profits from sale/rental of instruments; service charges for data collection and database creation; widening of market base

iv. Possible partners

1. Companies dealing in hydro-meteorological instruments
2. Companies dealing in development of electronic sensors & systems
3. Consultancy firms dealing in management of water resources

CONCLUSIONS

Hydrological instrumentation plays an important role in the hydrologic research and development. The lack of knowledge of proper instrumentation, latest models available and sources of supply lead to the use of conventional and age old instruments, which result in poor quality of data in many cases. The introduction of new technologies in the water sector has generally taken place slowly. The water profession, in general, has not fully appreciated the implications of technological advances, which are likely to affect water-use patterns and requirements. Although the availability of advanced instrumentation has considerably improved, less effort is directed in implementation of the new technologies in operational practice in India.

A whole new mindset and innovation will be needed to identify and solve future water-related problems, which will require substantial attention and additional investments to capacity building. It is hightime that we take cognizance of this lacuna in our data collection efforts and take corrective steps by addressing the issues of shortage of skilled manpower and lack of testing/repair/ maintenance facility for the new-age instrumentation. The paper summarises the various issues of hydrological measurements and instrumentation, and discusses the innovations needed, including the potential of PPP for this activity.

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