GEOGRAPHYCAL ANALYSIS OF WATER RESOURCES: ISSUES MANAGEMENT AND PLANNING IN INDIA

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Abstract:
Water is one of the most essential natural resources for sustaining life. Its development and management play a vital role in agriculture production. Integrated water management is vital for poverty reduction, environmental sustenance, and sustainable economic development. In view of the rapid increase in population, urbanization, and industrialization, the demand for water for meeting various requirements is continuously increasing. Therefore, we are facing numerous challenges in the water sector, which include reducing per capita water availability, the decline in groundwater table in many areas, and saltwater intrusion in coastal aquifers. The quality of surface water and groundwater is also deteriorating because of increasing pollutant loads from various sources. Climate change may also adversely affect the availability and distribution of water resources. This article presents an overview of relevant issues pertaining to development and management of water resources in India.
Keywords: Drought, flood, groundwater, recharge, contamination, arsenic

Introduction:-

Water is essential to human life. In fact, since 60% of the human body is water, it can be said that water is life itself. Without water, no field of human activity can be complete. Today, the world is debating if the flow of information is more important than the flow of energy. That is a good question. But the flow of water is still more important. It is fundamental to the economy and to ecology – and to human equity. The issue of water is becoming still more critical in view of climate change and related environmental concerns. Water is central to some of the flagship programs in India. The modernization of India may be largely dependent on the modernization of its water management. This is not surprising since India supports 17% of the global population but has only 4% of the world's water resources. Better and more efficient use of water is a challenge for Indian agriculture and industry alike. It requires to set new benchmarks in both villages and in the cities. In India, 54% of people are dependent on farming for their livelihood. Yet, their share of national income is only 14%. To make agriculture more remunerative and to improve the prosperity of farming communities, the Indian government has introduced many new projects. These include:

1. 'Har Khet ko Paani' (Water for Every Farm): This requires enhancing the supply and availability of water.
2. 'Per Drop, More Crop': This requires using drip irrigation and related methods to improve farm productivity while using the same volume of water.
3. 'Doubling Farm Incomes by 2022': To achieve this, the Indian government is rapidly expanding the area under irrigation, and completing 99 long-pending irrigation projects. Sixty percent of these projects are in drought-prone areas

Under the 'Make in India' mission, India is working to sharply increase the share of manufacturing in its GDP. From the current 17% of GDP, efforts are being made to take it to

25% by 2025. Industry requires a large volume of water. This is particularly true for the manufacture of electronic hardware, computers, and mobile phones. And these are all focus areas for 'Make in India'.

Currently, 80% of water in India is used by agriculture and only 15% by industry. In the coming years, this ratio may change. The total demand for water will also rise. The efficiency of water use and reuse, therefore, has to be built into the blueprint of industrial projects. Business and industry need to be a part of the solution. India is urbanizing at a rate not seen in its history. An effort is being made to build or upgrade 100 modern cities as part of the Smart Cities initiative. Reuse of water, solid waste management and better sanitation infrastructure and practices are benchmarks to assess Smart Cities. In urban India, 40 billion liters of wastewater is produced every day. It is vital to adopt technology to reduce the toxic content of this water, and to deploy it for irrigation and other purposes. This has to be part of any urban planning program.

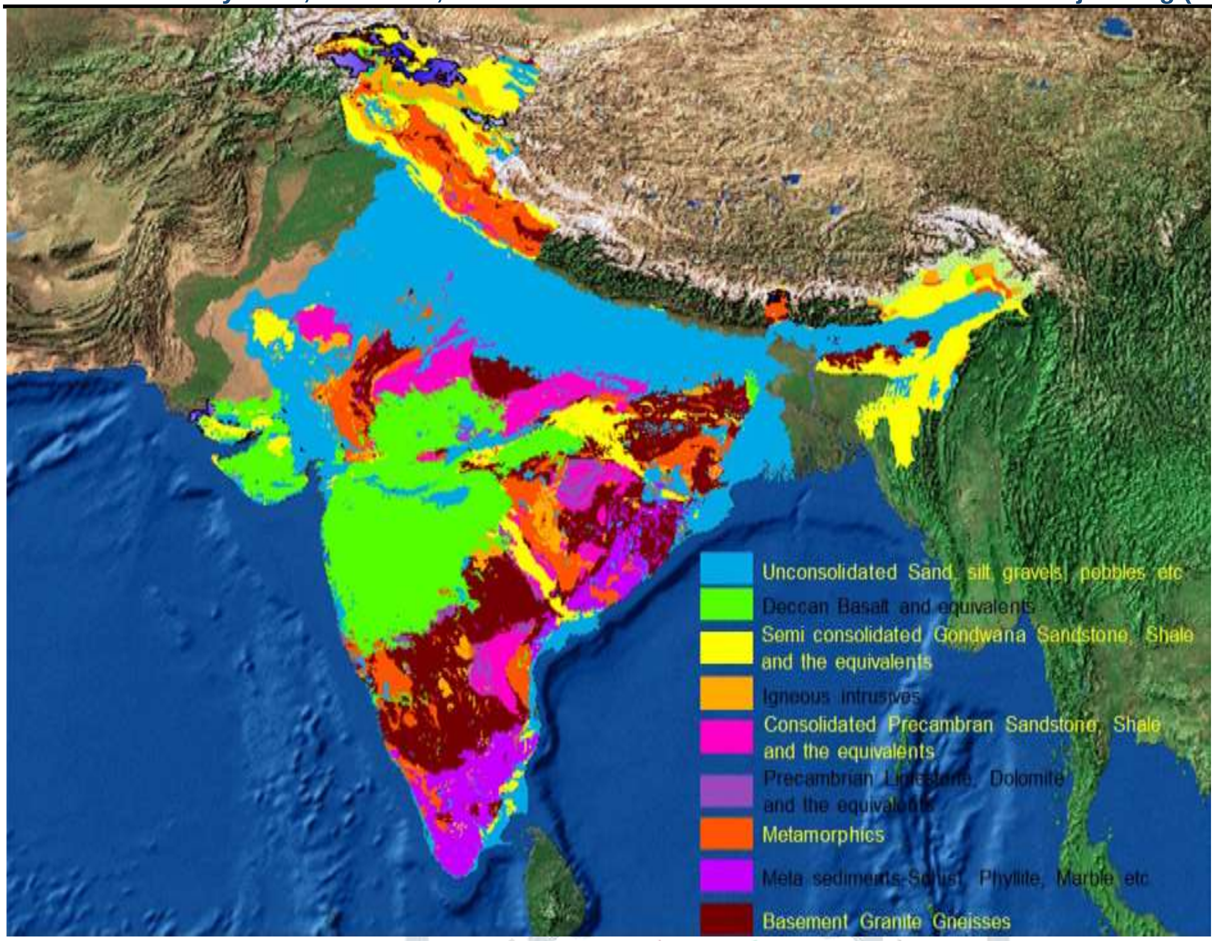
Water for Agriculture In order to meet the challenges of overall water scarcity scenario in the country, various measures can be taken, such as the construction of water harvesting structures, mass awareness among citizen for water conservation, construction of new water storage structures, interlinking of rivers, renovation, and repair of existing water bodies etc. Water budgeting and planning the cropping patterns for the oncoming agricultural season(s), the strategy for avoiding water-intensive crops to the extent in consultation with the relevant expert departments are also crucial for checking such situation. Micro-irrigation (sprinkler and drip) should be adopted to achieve more crops per drop. Six decades of investment in the irrigation sector notwithstanding, 45% of the 142 million hectares of agricultural land has only been covered under assured irrigation. With cost-intensive dam-based large projects unlikely to expand irrigation any further, the shift in focus for 'har khet ko pani' (water for every field) through in situ water conservation under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) is a step in the right direction. Water conservation and cutting down on wastage holds the key to bringing irrigation facilities to every farm in the country. This makes the introduction of sustainable water preservation practices and optimization of water resources just as important as the introduction of new irrigation facilities. Methods to treat and re-use municipal water are also required to augment irrigation water supply. A paradigm shift is required in agriculture by efficient water use via micro-irrigation alongside more investment in research on hybrid and high-yielding seeds, technology, and mechanization. Research is needed for climatesmart agriculture technologies for raising productivity and ensuring food security as the specter of climate change looms large.

Drought and Flood Management Significant regional variations exist in India when it comes to the experience with water. On the one hand, groundwater sources are being savagely exploited and depleted in some of the northern and western states. On the other hand, in eastern and north-eastern states, there is the challenge of overflowing rivers and regular flooding. Year after year, this damages human habitation and is leading to tragedies in countless families. Only a multi-stakeholder and multi-pronged approach can address such calamities. This includes achieving an interlinking of rivers where feasible. It also necessitates a basin-wide management of river systems to both keep rivers clean as well as serve the purpose of different types of users. The drought has many definitions, but mostly it originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. Drought should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration in a particular area, a condition often perceived as "normal". It is also related to the timing (i.e., the principal season of the occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness (i.e., rainfall intensity, number of rainfall events) of the rains. Other climatic factors such as high temperature, high wind, and low relative humidity are often associated with it in many regions of the world and can significantly aggravate its severity. There can be Meteorological Drought (degree of dryness and the duration of the dry period), Agricultural Drought (links various characteristics of meteorological or hydrological drought to agricultural impacts), Hydrological Drought (associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply), and Socio-economic Drought (associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought).

Because of the large variability of rainfall both in space and time, semi-arid regions are subjected to the problems of drought. The problems of arid areas wherever one good crop is not possible in normal years are quite different from those of semi-arid areas where one good crop is normally expected but it is frequently lost due to scanty rainfall or due to the variability of rainfall. Even normally high rainfall areas face the failure of rains and consequent upsetting of human water requirements. Water conservation and water management measures are need of the day to achieve a strong and stable economic base, especially in the arid and droughtprone areas of the country. There are no general solutions possible. They will have to be area specific, because of the hydrological peculiarities. It has also to be remembered that development of drought-prone areas cannot be modeled on the lines of the development of other favorably placed areas. The pattern of development of the drought-prone areas will have to be quite different from that of the others. Some of the methods that may be suggested as technical strategies to mitigate the adversities of drought are mentioned below.

Creation of surface storage, Planning for less dependable yield, Prevention of evaporation losses from reservoirs, Adjustment in sanctioned water to a reservoir or its releases, Reduction in conveyance losses, Equitable distribution, Maintenance of irrigation systems, Better irrigation practice, Irrigation scheduling, Cropping pattern, Conjunctive use of surface and groundwater, Watershed development, Creation of large storages, Integrating small reservoirs with major reservoirs, Transfer of water from water excess basins to water-deficit basins, In India, flood protection measures using embankments were in existence for centuries. This is evident from the old embankments constructed by private individuals for the protection of their lands. The inadequacy of the individual efforts in the sphere of flood control led to the governmental interest in the problem chiefly during the past century. As a result of this, a number of well-planned embankments were constructed on some of the rivers, which were causing recurrent flood damage. These measures were mainly to give protection to the commanded areas of the canal systems in northern India, and the deltaic tracts of east flowing rivers in Orissa, Andhra Pradesh, and Tamil Nadu. Flood management activities can be broadly classified into four major groups:

1. Attempts to modify the flood
2. Attempts to modify the susceptibility to flooding damage
3. Attempts to modify the loss burden
4. Bearing the loss All these measures for flood management can be classified as structural measures or non-structural measures.



Broadly, all measures taken up under the activity of "Modifying the flood" which are in the nature of physical measures are "Structural measures", while the others which are taken up as management tools without major construction activity are grouped as "Non-structural measures". The general approach to tackle the problem of floods in the past has been in the form of physical measures with a view to preventing the flood waters from reaching potential damage centers. This approach had been extensively constructed in the Godavari, Krishna and Cauvery deltas in South India and also in some areas of Indo-Gangetic plain. The main thrust of the flood protection program undertaken in India so far has been in the nature of taking structural measures like: • Embankments, flood walls, sea walls • Dams and reservoir • Natural detention basin • Channel improvement • Drainage improvement • Diversion of flood waters The present trend to reduce the losses incurred by flooding is equally towards non-structural measures. Some such techniques are mentioned below. • Floodplain management and zoning • Flood Proofing • Flood forecasting and warning • Flood fighting • Flood insurance 4. Water Quality of Ganga River.

River cleaning and development is a continuous process and National Mission for Clean Ganga (NMCG) supplements the efforts of state government in the cleaning of Ganga river by providing financial assistance to the state government. NMCG has sanctioned a total of 105 projects of sewerage infrastructure in Ganga basin states at an estimated cost of Rs 17,484.97 crores for river cleaning and Ganga rejuvenation. Out of these, 26 sewerage infrastructure projects have so far been completed resulting into creation of approximately 421 Million Litres per Day (MLD) additional STP capacity through construction/rehabilitation and approximately 2050 KM new sewer lines have been laid. Rest of the projects are under different stages of execution. The Central Pollution Control Board (CPCB) carries out water quality monitoring of river Ganga from Gangotri to West Bengal. Comparison of observed water quality (2017) with bathing water quality criteria indicates that Dissolved Oxygen which is an indicator of river health has been found to be within acceptable limits of notified primary water quality criteria and satisfactory to support the ecosystem of the river across all seasons and for an almost entire stretch of river Ganga. Biochemical Oxygen Demand (BOD) is found above the acceptable limit in part of stretches downstream of Haridwar to Kannauj, at Kanpur, at Allahabad, at Varanasi; and some stretches in West Bengal (e.g. Bahrampore, Serampore, Palta, Dakhshineswar, Howrah, Garden Reach, Uluberia and Diamond Harbour). The river water quality monitoring carried out in 2017 indicates improvement in water quality trends as compared to 2016. The Dissolved Oxygen levels are improving at 33 locations and are above the quality requirements of 5 mg/l. Biological Oxygen Demand (BOD) levels are reducing which is an improvement, at 26 locations and coliform bacteria count is reducing which is an improvement, at 30 locations.

Management of Groundwater Resources

Groundwater in India provides for about 60% of the country's irrigation needs, 85% of rural drinking water requirements and 50% of urban water needs. Unmindful exploitation of groundwater on large scale has led to a sharp decline in groundwater level and deterioration of water quality in major parts of the country. As per 2013 data, 4% of groundwater assessment units in the country are in a critical state and 10% in a semi-critical state due to over-exploitation and contamination. The reasons for this over-exploitation and contamination include increasing demand of groundwater for agriculture, industrial and drinking purposes; change in cropping pattern and growing of paddy and cash crops that consume large quantities of water; scanty rainfall in arid and semiarid regions; flat rate/ free subsidized electricity for extracting groundwater in certain states; haphazard sewage and waste disposal; large groundwater extraction during droughts when all other sources shrink; and rapid pace of urbanization resulting in reduced natural recharge to aquifers. Development of groundwater resources in different areas of the country has not been uniform. Highly intensive development of groundwater in certain areas in the country has resulted in over-exploitation leading to declining in groundwater levels. As per latest assessment of groundwater resources carried out jointly by CGWB and the States as of 2013, total annual replenishable groundwater resources of the country have been estimated as 447 Billion Cubic Metres (BCM). Net annual groundwater availability is estimated at 411 BCM. Annual groundwater draft for the entire country is estimated at 253 BCM per year. The stage of groundwater development is 62%. Mass awareness movement is required for restrained exploitation of groundwater. Decadal fluctuation analysis of water level has been done by Central Groundwater Board (CGWB) to assess the change in water level over last 10 years. Pre-monsoon (March/April/May, 2016) water level data when compared with the decadal average (2006-2015) indicate that more than 50% of the wells have registered decline in groundwater level, mostly in the range of 0-2 m, in almost all the States/UTs of the country, except few States namely Arunachal Pradesh, Goa, Pondicherry, Tamil Nadu and Tripura. The decline of more than 4 m was observed in pockets in the States/UTs of Andhra Pradesh, Chhattisgarh, Dadra & Nagar Haveli, Delhi, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Telangana and West Bengal. One of the key management initiatives to arrest the depletion of groundwater resources is to augment the resources through artificial recharge to groundwater and rainwater harvesting. Central Government has taken several steps for promoting rainwater harvesting measures in various parts of the country. Focus on development activities needs to be balanced by management mechanisms to achieve sustainable utilization of groundwater resources. There is a need for scientific planning in the development of groundwater under different hydrogeological situations and to evolve effective management practices. Groundwater management is the foremost challenge being faced by the organizations dealing with groundwater in the country. The activities of the organizations and policies affecting groundwater need to reflect the priority issues with the overall objective to provide water security through groundwater management in major parts of the country. Management of groundwater resources in the Indian context requires a combination of area-specific and problem-specific strategies depending on the climatic, geomorphologic, hydrological and hydrogeological settings.

Groundwater Legislation and Aquifer Recharge Water being a State subject, it is primarily the responsibility of the concerned State Governments to make suitable legislation to regulate utilization of groundwater. With a view to protecting groundwater regime and taking measures against over-exploitation and to ensure equitable distribution of this resource, the Union Government circulated a Model Bill to regulate and control the development of groundwater to all State/UTs in 1970. The Model Bill was re-circulated in 1992, 1996 and again in 2005 for adoption. So far, 15 States/UT's have adopted and implemented the groundwater legislation on the lines of the Model bill. Sixteen other States/UT’s have also initiated action for adoption and implementation of Model Bill. Central Groundwater Board (CGWB) has prepared a conceptual document entitled “Master Plan for Artificial Recharge to Groundwater in India”, involving groundwater scientists/experts. The Master Plan envisages construction of 1.11 crore rainwater harvesting and artificial recharge structures in the country at an estimated cost of Rs. 79,178 crores to harness 85 BCM (Billion Cubic Metre) of water. The augmented groundwater resources will enhance the availability of water for drinking, domestic, industrial and irrigation purpose. The Master Plan has been circulated to all State Governments for implementation. Central Groundwater Authority (CGWA) has issued directives to the Chief Secretaries of all States and the Administrators of all UTs to take measures to promote/adopt artificial recharge to groundwater/rainwater harvesting. Thirty States/UTs have made roof-top rainwater harvesting mandatory by enacting laws or by formulating rules and regulations or by including provisions in Building bye-laws or through suitable Government orders. CGWA has so far notified 162 critical/ overexploited areas in parts of NCT Delhi, Haryana, Punjab, Andhra Pradesh, Rajasthan, MP, Gujarat, West Bengal, Uttar Pradesh, Karnataka, Tamil Nadu, UT of Puducherry and UT of Diu for control and regulation of development of groundwater resources. For enforcement of the regulatory measures in these areas, concerned Deputy Commissioners/ District Magistrates have been directed under Section 5 of Environment (Protection) Act, 1986 to regulate groundwater development in these notified areas.

Groundwater Contamination Central Groundwater Board (CGWB) regularly monitors groundwater quality of shallow aquifers on a regional scale, once every year. Groundwater quality data generated during various scientific studies and groundwater quality monitoring indicate that groundwater in major part of the country is potable. However, some parts of various states are contaminated by salinity, arsenic, fluoride, iron, nitrate and heavy metals beyond the permissible limits of BIS. The possible sources of contamination of groundwater are either geogenic or anthropogenic in nature. Anthropogenic contamination of groundwater is due to industrial discharges, landfills, diffused sources of pollution like fertilizers and pesticides from agricultural fields etc. Various steps taken to check the groundwater pollution are –

♣ Control of industrial pollution under the provision of Water (Prevention and Control of Pollution) Act, 1974 by consent mechanism being applied by State Pollution Control Boards (SPCBs)/Pollution Control Committees (PCCs) in Union Territories.

♣ A mutually agreed time targeted program is implemented under Corporate Responsibility on Environment Protection (CREP).

♣ Establishment of Common Effluent Treatment Plants (CETPs) for a cluster of small-scale industrial units.

♣ Continuous water quality monitoring systems are being established on industrial units in the country, through the directives issued by CPCB, for getting real-time information on the effluent quality.

For improving the coverage of safe drinking water to the rural population, the Ministry of Drinking Water and Sanitation supplements the efforts of the states by providing them with technical and financial assistance through the centrally sponsored National Rural Drinking Water Programme (NRDWP). It is the State Governments who plan, design, approve, execute and operate & maintain the schemes for providing safe drinking water to the rural population.

Arsenic Problem in Groundwater Arsenic in groundwater is a geogenic contaminant i.e. caused by natural geologic processes. Arsenic-containing groundwater in Ganga River basin is hosted by the sediments deposited by the rivers during the late Quaternary or Holocene age The incidence of high arsenic in groundwater reported from various parts of the country, particularly in the Ganga plains is a serious threat to the health of human being. According to the World Health Organization website, long-term exposure to arsenic through drinking water and food can cause cancer and skin lesions. Over the last three decades, numerous measures have been initiated which includes the alternate arrangement for supply of arsenic-free water to the affected populace and providing arsenic removal plants. Arsenic occurrences in groundwater in these areas are highly sporadic in nature and all the sources in these areas are not necessarily contaminated. There is urgent need to make people aware about the negative impact of Arsenic in Ganga basin and other regions of the country. An exhaustive work plan is required to be prepared to meet the challenges posed by the presence of arsenic in groundwater. Everyone right from an individual to government including social organizations and NGOs have to join hands to make people aware of the arsenic problem. As a large population is dependent on groundwater resources for drinking purposes and is under the risk of health hazards, it becomes emergent to go for mitigation measures as well as alternate sources of water so that locals can be protected from the negative impact of arsenic in groundwater. Awareness of public on water quality, especially about poisonous arsenic contamination, need to be done and making the available alternate source of water with efforts of central and state governments as well as organizations and NGOs working in the field of groundwater. Tapping alternate safe aquifers, for supply of arsenic-free groundwater has been explored in many areas on a local scale; however, this approach would require extensive studies and analysis for mapping of groundwater availability, freshwater reserves and examine mobilization of arsenic in the aquifer, both on spatial and temporal scale, due to forcing perturbation. Under the National Aquifer mapping program (NAQUIM) of CGWB, special attention has been given to this aspect and water wells have been constructed tapping arsenic free aquifers using state of the art technology in parts of Ballia and Ghazipur districts of Uttar Pradesh. The present state of affairs of the growing arsenic occurrences demands a systematic translation of success stories of one place/region to another and formulating a comprehensive plan to mitigate the arsenic problem through a wider consultation process. Technological options to combat arsenic menace, in groundwater, to ensure supply of arsenic-free water, in the affected areas can be in-situ remediation of arsenic from aquifer system, ex-situ remediation of arsenic from tapped groundwater by arsenic removal technologies, use of surface water source as an alternative to the contaminated groundwater source, tapping alternate safe aquifers for supply of arsenic-free groundwater or combination of above techniques. Out of the above options, arsenic removal technologies and ex-situ treatment technique are being practiced widely to provide potable water to the people in the arsenic affected areas after treatment of contaminated groundwater. Their large-scale use in West Bengal, based on different operating principles, with various degrees of success and failure, has been reported.

8. Groundwater Resources: Assessment and Planning The current practice of groundwater resource assessment in India does not have any provision for the static storage that is necessary for mitigation of droughts – an important role of the groundwater system. There is a need to develop the discipline of Drought-hydrogeology by integrating the domains of drought analysis and groundwater modeling. This may broadly require following components: drought analysis, deficit irrigation, estimation of static storage need, incorporation of static storage in the planning process, development of soft models of the state variables. The role of this discipline is illustrated in the following sketch.

The current practice of groundwater resource assessment in India does not take any recourse to provide adequate outflows to sea to restrict the seawater intrusion. There is a need to develop model-based methodologies for estimation of the necessary outflows and hence the resource for an assigned extent of permissible seawater intrusion The agriculture sector is a major user of groundwater in India. The generic groundwater planning strategies need to be modified in two respects to address the planning issues related to agricultural groundwater development. Firstly, the decision variables have to be the crop areas rather than the pumping rate. Secondly, the feasibility of the assigned constraints has to be ensured for indefinitely long time duration. In spite of all the regulations and the monitoring, the ground reality is that many industries continue to clandestinely dispose of their untreated or partially treated effluents into the groundwater system. With the advent of modern numerical tools, it is possible to identify such aberrations. The current practice of estimation of recharge in India is to correlate it to the historical water table fluctuations and another source/sink terms – and to arrive at the average figure of the recharge coefficient (i.e., the fraction of rainfall appearing as recharge at the water table). The fraction so arrived at is assumed to be the stationary property of the region. This approach has been working well, but may not be tenable under changed climate. The recharge under the projected climate scenarios would need to be predicted by simulating the unsaturated flow – since there would be no historical data to fall back upon. Such predictive tools shall also come handy in understanding the impact of land-use change, forestation/deforestation on the recharge. Indian practice of groundwater resource estimation is oriented towards unconfined aquifers. For a credible estimation of the resource of deeper confined aquifers, it is necessary to identify their recharge zones where they outcrop as unconfined aquifers. Appropriate geophysical/ hydrogeological methodologies need to be firmed up for identification of the recharge zones. Research on these aspects may permit a more robust estimation of groundwater resource through the Groundwater Estimation Committee (GEC) norms in two ways viz. the lateral outflows (appearing as base flow in hydraulically connected drains) may be accounted for in the resource estimation; and the recharge estimates reached through the saturated zone water balance studies may be corroborated. Large areas in the country are contaminated with arsenic and fluoride due to geogenic causes. Additionally, groundwater mining has become a serious issue in many parts of the country. Innovative indigenous techniques need to be developed to address these issues.

Participatory Water Management Water shortage is one of the biggest problems that the country faces today. A big reason for this problem is the poor management of available resources. On one hand, we over-exploit our rivers, lakes, groundwater and other sources of water, but on the other hand, we allow colossal amounts to run off into the sea unutilized. The role of participatory water management needs to be emphasized in addressing the problem of water scarcity in the country. To address this problem, the Government, the civil society and the local level communities must all work together to find ways to preserve, protect and augment the available water resource. There are examples from states like Maharashtra and Gujarat where such participatory management of water have helped turn waterstarved, barren farmlands into fields producing multiple crops in a year. Long-term sustainability of water resources can be assured only through holistic management programs that take care of both demand-side and supply-side management. Supply-side management focuses on management of aquifer systems and recharge of groundwater resources while demand-side management involves efforts at arresting the decline in groundwater levels by regulating the withdrawals and increasing water use efficiency. Demand side management is thus dependent on community participation. It requires the community to make efforts at ensuring that water is extracted in a sustainable manner, the cropping pattern is suited to the area, drip/sprinkler irrigation is encouraged, and people of the community resort to water budgeting. There is a need to promote and encourage participatory management as a solution to long-term, sustainable development of water resources in the country. Participatory management recognizes groundwater as a Common Property Resource. When this management method is employed to manage groundwater, the local communities themselves regulate the extraction and use of water and are also proactive in augmenting and recharging the resource. Participatory management of groundwater has resulted in many success stories in the states of Maharashtra (Tamaswada Nalah Treatment), Gujarat (Upleta Taluk, Rajkot), Maharashtra (Beed, Jalna, Satara) Andhra Pradesh, Tamil Nadu (Annavasal) to name a few.

National Water Informatics Centre National Water Informatics Centre (NWIC) has recently been created by the Ministry of Water Resources, River Development and Ganga Rejuvenation. It would be a repository of nation-wide water resources data and would work as a Subordinate Office under the Ministry of Water Resources, River Development and Ganga Rejuvenation. The management of water resources is a highly complex and tedious task that involves the expertise of multidisciplinary domains and depend on historical and real-time reliable data and information. For this, the first requirement is to develop, maintain and update regularly a comprehensive "Water Resources Information System" (WRIS) in public domain for awareness and involvement of all concerned for effective integrated water resources management. This is also a pre-requisite for scientific assessment, monitoring, modeling and Decision Support System (DSS) and Integrated Water Resource Management (IWRM). In this backdrop, NWIC is expected to provide a 'Single Window' source of updated data on water resources and allied themes; and valueadded products and services to all stakeholders for its management and sustainable development. Functions of NWIC include – 1. Provide single window source of updated data on water resources and allied themes and also valueadded products and services to all stakeholders for its management and sustainable development. 2. Empower, inform and enrich every citizen with up to date and reliable water data and information (excluding classified data) through web-based India Water Resources Information System (IndiaWRIS) on GIS platform. 3. Develop value-added products and services for all aspects of integrated water resources management through research, capacity building, linkages, outreach and better governance in water resources sector. 4. Collaborate with leading research institutes nationally as well as internationally to provide technical support to other central and state organizations dealing with water, emergency response for hydrological extremes.

Research and Development Needs A workshop to identify the R&D needs in the broad areas of Hydrology and Water Resources was organized in IIT-Guwahati, on behalf of the DST-PAC on Civil and Environmental Engineering, during July 17-18, 2014. The recommended R&D areas, arising from lead presentations followed by extensive discussions among all participants, are listed below.

♣ Development of indigenous low-cost sensors for climatic, hydrologic, and water quality variables ♣ Integrated assessment of surface water, groundwater and sediment yield (including source) in a river basin ♣ Quantification of hydrologic alterations (e.g., due to land use – land cover, sand mining, extensive irrigation etc) and climate change in a catchment ♣ Comprehensive studies on lakes and wetlands including surface water and groundwater interactions ♣ Research on stationarity properties of hydro-climatic processes in India ♣ Hydrologic assessments in ungauged basins ♣ Studies on eco-hydrology including estimating environmental flows for different locations in major basins ♣ Development of techniques for monitoring and mass balance for Himalayan glaciers and computing snow/glacier melt. ♣ Urban flooding: mapping, design aspects of storm sewer networks, and forecasting ♣ Innovation in improving agricultural water use efficiency by better sensors, weather forecasting, and models ♣ Development of discipline of Drought-Hydrogeology dealing with the modeling-based planning of static storage and groundwater development to mitigate droughts ♣ Model-assisted planning of groundwater development in coastal aquifers ♣ Development of discipline of Agricultural-Hydrogeology dealing with the modeling-based planning of groundwater development for agriculture ♣ Development of discipline of Forensic Hydrogeology dealing with identification of the pollution source (including the camouflaged ones) ♣ Development of predictive numerical tools for recharge estimation under changed climate ♣ Estimation of the resource of deep confined aquifers; identification of recharge zones ♣ Development of tracer-based field procedures for estimation of recharge and base flow contribution ♣ Groundwater mining and arsenic contamination – remediation strategies ♣ Riverbed mining ♣ Design standards for erosion resistant hydraulic structures ♣ The vulnerability of embankments to breaching ♣ Performance evaluation of existing infrastructures for flood prevention ♣ Development of physically-based watershed models for rainfall and runoff, and flood routing analysis ♣ Design of snow gauge network for Upper Himalayan basins and development of snowmelt runoff models ♣ Evaluation of available flood forecasting methods and development of indigenous methods ♣ Development of non-conventional river discharge estimation techniques ♣ Accounting for non-stationarity in flood frequency analysis ♣ Spatial precipitation representation required for watershed modeling Studies ♣ Development of observatories in different hydro-agro-climatic regions dedicated to studying integrated hydrological processes in small catchments. ♣ Calibration/ Validation of remotely sensed hydrological variables ♣ Testing or verification of coupled hydrological models ♣ Rainfall estimation using microwave remote sensing ♣ Hyperspectral remote sensing ♣ GRACE (Gravity Recovery And Climate Experiment) ♣ Hydrologic alteration due to socio-economic factors and holistic approach of restoration ♣ Futuristic optimal design of urban drainage system using justified design storm considering ecologically sustainable watershed management/renovation using EMPs including rainwater harvesting ♣ Mitigating surface and groundwater pollution due to point and non-point source pollution through modeling and management practices ♣ Comprehensive hydrological scenario development under different possible development model for minimizing flood risk ♣ Hydrological challenges in riverfront development in a situation of high temporal variation of precipitation and sustainable river mining ♣ Climate change and extreme events ♣ Capturing orographic influence on precipitation distribution while projecting climate change impacted future precipitation ♣ Identifying homogeneous hydrological region for possibly reducing uncertainty in climate change projection ♣ Optimizing ecological management practices considering carbon sequestration potential of vegetative measures ♣ Basin level studies for impact assessment of climate change, quantification of uncertainties and suggesting mitigation/adaptation measures

Concluding Remarks Most of the water planning and development in the country has been done as per administrative boundaries rather than by using river basins as the hydrological unit. This has led to water conflict as most river basins are shared by several states and water demand for meeting domestic, industrial and agricultural needs within each state has gone up significantly. In the absence of river basin management plans and active river basin authorities, these issues have intensified.

The variability of water resources across India demands a basin-by-basin analysis. Variation in rainfall means replenishment is unevenly distributed over time. This makes the management of water including with storage facilities for recharge, even more important than just absolute quantity of water availability. A localized water management approach is need of the hour. It should empower village and neighborhood communities and build their capacity to manage, allocate and value their water resources. Any 21st century water policy must factor in the concept of the value of water. It must encourage all stakeholders, including communities, to expand their minds – and to graduate from allocating a quantum of water to allocating a quantum of benefits. Of course, this quantum of benefits will be dynamic. It will inevitably be linked to the mapping and forecast of livelihood patterns in human society. And these keep evolving.

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