Advancements in techniques in groundwater regime monitoring and data base management planning facilitated through Hydrology Project

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Abstract

The *Hydrology Project* (HP) is in the process of establishing a *Hydrological Information System* (HIS) at agency, state and national level for hydro-meteorological, surface water and groundwater quantity and quality data. The HIS envisaged, comprises the infrastructure of physical and human resources to collect, process, store and disseminate data on geo-hydrological and hydro-meteorological variables. In creating the HIS the advancements taking place in the field of electronics, computers and communications is being exploited for data gathering, organising data, establishing data warehouse, and provide a decision support systems to the water resource management agencies. HIS will facilitate standardised documentation of data through out the country, quick and easy interpretation, provide gateway for advanced data analysis through modeling for visualising the system response to different situations as well as disseminate information and knowledge to all the agencies and the actual water users.

The physical infrastructure includes observation networks, laboratories, data communication system and data centers equipped with databases and tools for data entry, validation, analysis, retrieval and dissemination. The data centers include a *State Data Storage Center* and *Data Processing Centers* at the professional agencies. The state data center is a storage facility for reliable data sets that are processed, validated and authenticated at the data processing centers. As such, the processing centers are required to include a comprehensive hardware and dedicated software system that will be able to accommodate all the processing and temporary storage involved.

HP is being implemented in the eight states of Andhra Pradesh, Gujarat, Kerala, Karnataka, Madhya Pradesh, Maharashtra, Orissa and Tamil Nadu. The infra-structural development and implementation of the proposed HIS in the project area is vested with the concerned Central and State agencies operative in the project area. These participating central agencies are the Indian Meteorological Department (IMD), Central Water Commission (CWC) and Central Ground Water Board (CGWB) and the State agencies are the Irrigation (or Water Resources Departments) and Ground Water Departments of the respective States.

The present paper discusses the up-gradation of the ground water monitoring network through dedicated piezometers, introduction of Digital Water Level Recorders for continuous water level monitoring, standardisation and organisation of data through data entry software, capabilities of the dedicated groundwater application software being procured and the future interpretations & reporting capabilities of the agencies.

1.0 Background

In India the major challenge to be faced by the planners in the next millenium will be related to allocation of large quantities of groundwater resources (potable) to serve as drinking water source to the emerging urban pockets, industrial belts, cities with large slums and rural habitations. During the same period groundwater demand for irrigation, industrial needs and cultural activities will also increase disproportionately. Major threat to groundwater availability will not only is due to increased exploitation, reduced recharge but also through pollution from industrial effluents, urban waste disposal, poor sanitary conditions and saline water intrusion. Groundwater quality problems and high incidence of water-related diseases can become a consequence of these problems. Thus there is an urgent need to anticipate and avoid these situation by developing new technologies for delineating potential groundwater sanctuaries, systematically develop them, scientifically manage the resource for ensuring its sustainability and bring in legislation to prevent overuse/ misuse of the scarce resource.

Watershed development, afforestation, protecting the wild habitats, treatment of effluents, integrated development and management of the water resources will have to be enforced strictly by the authorities responsible for managing the groundwater resources. Central Ground Water Authority will come to play a major role not only in formulating the groundwater development and management policies but also as a pressure group to see the recommendations are implemented. This would call for framing up of groundwater development and protection policies, recommending enactment of legislation, developing institutions for implementing the acts and disseminating information to the water users.

Integrated management planning of groundwater resources will require authentic data and information emerging from the different states that can be easily accessed through a data bank, which can be analysed using simple analytical tools, systematically interpreted and presented as maps, charts and sections that can be well appreciated even by non-specialists.

2.0 Establishment of Hydrological Information System (HIS) under the Hydrology Project (HP)

Lack of systematic archiving of data and absence of uniform data collection and storage system has hampered easy data retrieval and data exchange between the agencies. The need for interactive data management system was highlighted in India’s National Water Policy (MOWR1987).

The Hydrology Project (HP) implemented through the financial assistance from the World Bank is in the process of establishing Hydrological Information System (HIS) which will be validated data storehouse for all water resource information. CGWB will be responsible for managing the national groundwater data center in

Faridabad with regional data centres in all the Regional offices. The eight participating states in the Hydrology Project will establish the state level groundwater data centres in the respective states.

HIS will store validated information on the historical monitoring wells/ piezometer / exploratory wells recording the static data related to the location, construction, well design, lithology and dynamic data related to water quality analysis results, water levels and rainfall. All the different varieties of data will be systematically organised. Application software will include data base tools supported by tools for graphic presentation, statistical analysis, GIS and reporting features.

3.0 Improvement in Groundwater regime monitoring

The HIS can be used a decision making tool only when the data stored is reliable , representative, consistent and relevant. In order to ensure the reliability of the data that forms part of the HIS number of improvements in groundwater regime monitoring have been taken up through:

3.1 Construction of dedicated piezometers.

25,000 water level monitoring structures have been providing water level and water quality data spread over the eight states where in HP is operational. Most of these monitoring structures are open dug wells, which are privately owned which largely provide data on the shallow phreatic aquifers. Numbers of them tend to dry up in summer leading to periods of data loss. Under the HP dedicated piezometers have been constructed that provide information on lithology, water bearing zones, discharge as well as serve as committed source for water level, water quality monitoring and hydrogeological/geophysical investigations.

A piezometer is a purpose-built, non-pumping observation well that facilitates measurement of vertically averaged piezometric head of a single layer. The selected layer is an aquifer, though for some specific studies it may be thinner than an aquifer (for example, for monitoring vertical variation of the head in an aquifer). A piezometer taps only the selected layer, blinds the rest of drilled strata and finally isolates the selected layer from the rest of the drilled strata and ground by properly placed seals. The tapping is accomplished by a screen and the surrounding gravel pack in the unconsolidated formation and is left as a naked hole in the consolidated formations. Water elevation in the piezometer represents the vertically averaged piezometric head of the tapped layer. Piezometers are also used for sampling the groundwater from the tapped aquifer for water quality monitoring.

The Hydrology Project envisages the construction of 6434 piezometers. Large Numbers of piezometers have already been constructed and operatinalised, which are regularly sending out water level and also water quality data.

The operation and maintenance component related to the piezometer network would have to become an essential task for ensuring the proper functioning of the piezometers. The maintenance work should including flushing the borewell/tube well to remove the silt settled at the well bottom, open up the fractures/ remove the fines around the screen, deepen the wells in areas subjected to lowering of water levels, replacement of piezometers which have collapsed / well assembly corroded / wells dried up.

Water level data emerging from poorly functional or non functional/ non representative piezometers will make the groundwater monitoring a wasteful exercise and at times can prove disastrous from groundwater development planning and management point of view.

3.2 Installation of Digital Water Level Recorders

Manual measurement of water levels has been practiced since the historical past. Large increase in the number of observations wells, long distances between the monitoring wells, seasonal in-accessibility and the need for water level data at closer intervals has prompted the need for automation of the water level measurements through the use of Digital Water Level Recorders (DWLR).

The DWLR capture the water level data at the desired frequency, have high degree of accuracy , and are reliable and easy to operate. The water level measurements can be carried out for pre-defined frequencies and the data downloaded from the instrument at the convenience of the user. The data can be incorporated with the database and analysed in the office.

Under the Hydrology Project 5517 DWLR's are to be installed on the piezometers spread over the country. Already over 500 DWLR's have been installed and have been sending out data for over 15 months. Analysis of the downloaded DWLR data shows that the high frequency water level measurements provide new information related to diurnal variations in water levels, rainfall – recharge response, impact of watershed and artificial recharge activities on regional water levels and provide early warning signals regarding seasonal water level decline. The greatest impact of the high frequency water level measurements has been in triggering the hydrogeologists to come out of their conventional understanding on the dynamics of the groundwater system. Analysis of high frequency water level measurement data has already prompted the hydrogeological to update the groundwater resource estimation computations, make approximations of the specific yield and estimate the amount of recharge required to trigger groundwater rise.

The frequency of water level monitoring using the DWLR has to be finalised for different areas. The monitoring frequency should be dictated by the water level monitoring objectives, hydrogeological set-up of the area, local microenvironment set up of the area and the nature of the groundwater problem. There should be no effort to standardise the monitoring frequency across the state/ country. The different types of instruments being procured under the HP allow measuring interval from a minimum of 3 seconds and the maximum of 7 days. Over exploited areas canal command areas, coastal areas and areas having limited recharge events, obviously need high frequency of monitoring which could be vary from monitoring at 1 hr interval to 2, 6, 12 hourly, daily or weekly, which is area/ problem specific. In the Linear measurement frequency, the measurements will be carried out at the same regular, unvarying sample interval.

In formations that are largely depended on precipitation for recharge there is a need to have varying monitoring frequencies for the recharge and discharge phase. In the pre-monsoon period the monitoring could be daily and in the post monsoon phase it could be hourly monitoring or even lower as per the requirement

3.3 Water Level & Water Quality network Optimisation

Optimisation of the piezometric network has been carried out by integrating the CGWB and State Agency piezometers. Optimisation of the water level network is required for estimating the average piezometric head in an area at various discrete times. Such an averaging is required for estimating the groundwater storage. The network also enables understanding of the spatial distribution of the piezometric head at different discrete times- necessary for understanding the groundwater regime and also for the aquifer response modeling. Based on the optimistaion network task carried out additional requirement of an additional 1482 piezometers has been identified by the different state governments. A decision on the same is being considered by the Government.

Water quality monitoring network optimisation is being carried out to establish the spatial variability of the quality parameters, provide early detection of different types of pollution, monitor water quality changes in overexploited areas, coastal areas, canal commands and other vulnerable areas. In the water quality network optimisation parameters to be analysed have also to be finalised. Availability of sparsely distributed water quality data has made the water quality network review a slow process, as a result the water quality network optimisation is still in the final stages of completion

4.0 Data organisation under the HIS

HIS will provide reliable data sets for the purpose of long term planning, designing and estimation of water resource and water use systems and for research activities in the related aspects. It is also desired that the system will function in such a manner that it provides the information to the users in time and in proper form. The scope of HIS is not extended to provide the data to the users on a real-time basis for short-term forecasting or operational purposes. The data will be made available to the users only after necessary data validation with a maximum time lag of upto a season.

To ensure that the objectives of the HIS are fulfilled the data being collected will have to systematically organised, stored, validated, analysed and interpreted. Systematic organisation of the groundwater data has been initiated since Aug 1997 and is in the advanced stages of implementation by CGWB and State Agencies. To begin with historical water level and water quality data from the already existing monitoring wells has been largely brought into one single format. For the sake of standardisation the technical consultants to HP, have developed a Ground Water data Entry Software (HIS-GW/DES) on Microsoft Access.

HIS-GW/DES has been contemplated as a platform essentially to standardise the data organisation procedures by all the agencies participating in the Hydrology Project. The *HIS-GW/DES* software systematically stores in an organised format all information related to the piezometer construction, lithological data, geophysical electrical logging data, pumping test results, ground water levels and water quality results.

The added features of the *HIS-GW/DES* includes facilities for appending DWLR data, importing rainfall data, generating integrated hydrographs, carrying out standard primary validations of the data, generation of geophysical logs, generation of standard and customised reports. The *HIS-GW/DES* software, customized to the requirement of the users has been made available to all the agencies on CD. The data organised in *HIS-GW/DES* will be compatible with the dedicated groundwater application software.

The data entry software has no analytical capabilities, which will be the task of the dedicated software, which is likely to be implemented in the Year 2000. In order to carry out specialised analysis until the implementation of dedicated software, the data entry software provides facilities for exporting the data in an ASCII format which is compatible with specialised application software.

Bulk of the historical water level and water quality data available with CGWB in dbase format have been converted to HIS format. The data from the newly drilled piezometers are being computerised using the *HIS-GW/DES* software.

Training has been provided to all the agencies in using the software.

5.0 Establishment of Data Centres

As part of the establishment of HIS different levels of data centres are established where in the data is being brought into the database.

In the ***District Data Processing Centres*** all field data are being entered in the computer and stored in a temporary database. Primary validation (entry checks and data integrity will be checked and feedback given to the field officers. The computerised data will move up to the Divisional/Regional Data Processing Centre.

In the ***Regional Data Processing Centres***, data integration from the different districts will take place and advanced secondary data validation carried out. The data will be stored in temporary databases. After validation the data will move to the State Data Processing Centres.

The main activity of the ***State Data Processing Centre*** is integration of all data for the entire state, final data validation, completion, analysis and reporting. Here, the data are stored in temporary databases. At the end of the hydrological year, once the data have been properly validated, the (authenticated) processed data will be transferred to the State Data Storage Centre.

The ***State Data Storage Centre*** will store and administers the storage of all field and (authenticated) processed hydrological data collected in the State, and makes the data available to authorised Hydrological Data Users. As a State archive, it also maintains an HIS-Catalogue of all data stored in its own database and those stored in the databases of the other states and of the Central Agencies.

Since data processing activities will be carried out at more than one level within each agency as well as between different agencies adequate data communication links have been envisaged.

6.0 Dedicated Groundwater Application Software

The Hydrology Project envisages a *dedicated software* for groundwater data processing centers. The software is expected to have the capability to perform a variety of tasks related to data entry, processing, validation and dissemination of mostly periodic reports, under an integrated software environment that comprises a data base, GIS functions and application tools. Much specialized processing like numeric modeling, shall be done elsewhere, but the dedicated software would prepare the data that would be compatible with popular modeling softwares.

The *dedicated software* will have tools that will carry out data validation and facilitate production of reliable data sets that can be used for generating maps, time series graphs and groundwater resource assessment through a lumped water balance/*GEC-97* approach. The capabilities of the software will include:

6.1 Automatic contouring

The production of contours and the processing would follow c*omputer assisted automatic procedure*. The user can specify the grid spacing, contour interval, selects the appropriate algorithm of interpolation from an array of built-in algorithms for generation of the contours.. The user, based on his professional judgment and guided by relevant information (thematic maps, hydrogeological cross sections etc.) can edit some or all the contours manually. The contours can be modified by the user especially while extending water level contours near a river boundary / dyke etc

6.2 Time series analysis

For representing the temporal variation of water table/ piezometric head/ rainfall/ water quality parameter for a given spatial location, time series hydrographs can be generated automatically. The interval between the successive data can be chosen as uniform through out the series or may be non-uniform. The dedicated software will have number of options of the time series such as Auto/ cross Correlation analysis, Stationarity analysis, Spectral (or Fourier or Harmonic) analysis, Co-Krigging

6.3 GIS Capabilities

Much of the processing requirement at the GW processing centers include layer-wise data collection, processing, interpretation and dissemination in the form of cross sections and maps will be done using GIS features of the software. The GIS capabilities of the software will include:

- *map entry in the form of scanning, digitizing or import of conventional files*
- *raster to vector conversion*
- *integrated map generation by posting information on base maps*
- *preparation of contour maps and manual editing capabilities*
- *manipulation of layer-wise information from original/manually edited contour and thematic maps and database, to yield combined spatial derivatives (such as water table fluctuation and specific yield maps, change in water storage and quality parameters, slope and rock formations) and permit basic numerical computations like interpolation, differentiation and integration*
- *calculation of area between contour lines according to given value range, mapped units (such as rock formations, crops), or manually specified area*
- *preparation of slope/gradient maps from contour maps*
- *well log presentation along specified cross section lines for the preparation of hydrogeological cross section*
- *computation of spatial average rainfall from point data*
- *generation of 2D and 3D subsurface drawing using data stored in database*
- *preparation and manipulation of spatial and layer-wise information for specialized modeling software*

6.4 Ground Water Resource Assessment

The dedicated package will have customised water balance computations and the GW resource assessment features following the methodologies detailed in Ground Water Estimation Methodology (GEC, Ministry of Irrigation, GOI, 1984 and its latest 1997 modification) . The data support for the resource assessment will be automatically accessed from the database on defining the unit area and assessment period. However, refinement and enhancement of data input will be possible by the GIS capabilities through manipulation of layer-wise information from maps and database to yield combined spatial derivatives. The main components of these computations include :

- *calculation of monsoon recharge according to ad-hoc norms (normal monsoon rainfall x area x infiltration factor). Different norms are used for different geological rock formations and refinement may be introduced over different ground slope categories*
- *calculation of the monsoon recharge and stage of development from water balance of the monsoon period*
- *validation of the spatial distribution of the specific yield of water balance of the dry period*

6.0 Future Scenario

Availability of HIS data as an oprganised database, combined with high speed computing power of the computers, groundwater modeling will become a regular task for groundwater problem solving. Modeling although not part of dedicated software the data can be exported to standard modeling software. With the use of groundwater modeling techniques anticipation of different groundwater phenomenon / problems will become a rule and the surprise elements an accident.

The dedicated software that will come with GIS features combined with high resolution graphic displays, significant visualisation capabilities will be made available to hydrogeologists. Realistic 3D images can be created of hydrogeologic structure. When 3D distribution of groundwater properties such as head, solute concentration are superposed on such an image the hydrogeologic features and parameters of importance to a groundwater resource will become apparent. This would help in building hydrogeologic intuition. 3D visualisation and animation will successfully communicate concepts through compelling images. A pitfall however could be a 3D colour images can be impressive despite lack of data.

Overexploitation of groundwater resources is a key issue. In areas with overexploitation the common approach is to regulate water use, initiate number of programmes for preservation and management of groundwater, rather than systematically manage the available resources. In such areas only rough and unverified estimates of recharge are available. In such areas HIS can help guide ground water research, development protection and management.

Understanding the seasonal variations in groundwater chemistry, hydrochemical zonations in the different aquifer systems, hydrochemical evolution of different types of groundwater will become standard tasks for the groundwater agencies.

Optimising the data base capabilities, the abundant litho-logical data can be used in consonant with the less abundant aquifer test parameters data and using geo-statistical tools best possible estimates of the aquifer test parameters can be generated that can be an useful input to modeling.