REMOTE SENSING APPLICATIONS IN GROUNDWATER ASSESSMENT

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1.0 Introduction

Groundwater wells existed since 3000 BC, when Indus valley civilization flourished on the earth. Groundwater constitutes nearly one-third of the world's fresh water resource. In many areas, it is the only source of water. Groundwater forms an important part of hydrological cycle. A part of rainwater percolates in to the ground enriching the groundwater resource. The rivers are influent or effluent i.e. they respectively contribute to the groundwater resource or they receive their flow from groundwater discharge.

Groundwater acts as a water reservoir, which can store the water when available in plenty during rains and release it when required. It is relatively free from impurities e.g. pathological organisms, turbidity, radio-chemical contamination etc. Though, there are cases reported of the groundwater pollution caused by industrial effluents, municipal sewage and solid waste dumps, river sediments in delta regions etc. Groundwater may be saline in the inland areas or the coastal area due to fossil sea water or seawater intrusions. The watertight saline groundwater aquifers are also utilized for industrial waste disposal. Groundwater resources are utilized for municipal water supply, irrigation, and industrial uses. With wide applications and good quality of this resource, the assessment of this resource is very important.

2.0 Water Bearing Materials

Groundwater is stored below the ground within the pore spaces of the soil grains or secondary pores of the rocks. Not all the water stored below the ground is utilizable and thus the groundwater storage reservoirs are classified as follows:

Aquifers: These allow storage of the large quantity of water and faster movement of this water. Example of these are coarse sand, medium sand, fine sand, gravel layers, rocks with weathered layers, faults, fractures etc. The medium sand being the best aquifers.

Aquifuge: This does not store or allow the movement of water. Examples of these are solid granites etc.

Aquiclude: These store large quantity of water but allows very slow movement and are not suitable groundwater reservoirs. Examples of these are thick clay layers.

Aquitard: This store small quantity of water and allows slow movement of the water. Examples of these are thin clay or sandy clay layers.

Thus, it is clear that the availability of the groundwater depends on the water bearing material beneath the ground, their arrangement and extent; and the groundwater balance in the region. When good aquifers exists but the area in under groundwater overdraft, groundwater utilization can not be sustained in long run due to excessive cost of pumping etc.

3.0 Groundwater Exploration/ Investigation

Since the groundwater aquifers and reservoirs are located below the ground and are invisible to eye, many of the investigation techniques draw inferences about it from certain indicators. Apart from this, exploratory drilling provides direct information. Due to higher cost of drilling and point information provided by them, many other indirect methods are also applied in the groundwater investigations. One such technique i.e. remote sensing is deliberated here. Various indicator of availability/ non availability of good groundwater reservoirs are listed below:

Alluvial Areas

Paeleao channels

Anomalous vegetation

Floodplains

Hard Rock Areas

Fractures/ faults/ foliation

Physiography

Geomorphology

Lithology

Anomalous vegetation

Drainage characteristics

Weathering

The alluvial areas have generally good groundwater potential. However, certain geomorphological feature e.g. floodplains, pealeao channels are very good groundwater reservoirs. The are also very good locations for induced recharge. These aquifers can be exploited for uses such as municipal water supply etc. The geomorphological features are very well mapped from remotely sensed data. In the recent floodplain, the meandering rivers and sandbars are included. Water is seen as blue to black in color on the FCC. Sand is seen in white, yellow, reddish white color etc. The sandbars may have vegetation establishing on them. Other features e.g. meander scars are not good source of groundwater since they consist of clays.

Hard-rock areas have lower groundwater potential than alluvial areas. The groundwater aquifers are formed in the area in weathered/ faulted/ fracture zones. The faults/ fractures/ dykes are manifested in terms of linear features on the satellite images. River channels are oriented along these features. There may be differences in soil/ vegetation/ slopes/ topography across these features and these are manifested on the satellite data.

Drainage density is related with the weathering, rainfall, slope, vegetation etc. Higher density indicates occurrence of more surface runoff over the land surface and thus less infiltration and thus less enrichment of the groundwater aquifers. Thus, drainage density can be useful in groundwater potential mapping. Drainage density is also indicator of lithology e.g. siltstone will be more erodible than sandstone.

Geomorphological mapping e.g. mapping of duricrusts, pediments, buried pediments, valley fills areas and their characterization is very useful in groundwater investigation. Not all features can be mapped using remotely sensed data. Ground truth is needed for mapping pediments. The above features have increasing order of groundwater potential.

Pediments: Pediments are the features, which earlier believed to be the depositional features. These are rock surfaces, which have gentle slope than the duricrusts and are located at the foothill. At times, they may be covered by sediments e.g. boulder, rocks, sand, clay etc. When, they are buried deeply under the sediments they are called buried pediments. The units have poor to moderate groundwater potential. The fault/ fractures in the duricrusts may extend in the pediments and are good source of groundwater. These features are the products of the arid climate. Break of slope is present between the basement rock of duricrust and pediments.

The geomorphological maps are often combined with the lithological maps to produce hydrogeomorphological maps. In these maps, the groundwater potential of each unit is assessed using exploratory drilling. The geological maps are generally available for the areas or can be prepared using remotely sensed data and field data etc.

The areas having good groundwater potential may have anomalous exuberant vegetation. These areas can be mapped in the remotely sensed data. But, often due to anthropologic factors such areas may not exists.

Waterlogging

In another case higher groundwater table may cause waterlogging in areas. The waterlogged areas with surface inundation/ moist soil have been mapped in the past. Some times, the extent of such areas may not be large and may not be visible in the coarse resolution remotely sensed data. Such areas may exist near the canals. The waterlogged areas also support crops e.g., paddy and natural vegetation and such areas can be mapped. The waterlogging may also develop in unfavorable ground water condition e.g. saline groundwater areas. In such areas, there is no conjunctive use of water and thus only recharge component exists causing the rise of the water table and such areas may develop due to the canal irrigation. Waterlogging by no means is indicative of the good groundwater potential but requires amelioration.

Groundwater Table/Depth Mapping

Conventionally, groundwater maps were prepared by manually interpolating the ground water levels. Presently, the maps are also prepared using GIS and other interpolation software (e.g. Surfer). GIS and software based option is better, but requires investment into the softwares and hardwares. These also involve costs in maintenance and updating. In GIS and interpolation softwares, the kriging is often used interpolation method. Various models e.g. Gaussian, spherical, linear, exponential can be used depending on the nature of experimental semi-variogram generated from the data. Using these plots and variance of the data, the parameters e.g. sill, range and nugget are determined. The sill is generally equal to the variance of the data. In general, one data set is sufficient to develop the parameters. The parameters can be used in the other year/ season data.

Lithological Mapping

Lithology is an important determinant in the groundwater potential mapping. The lithological maps are prepared by Geological Survey of India (GSI) for many parts in India. Such maps can be used. The maps can also be prepared using remotely sensed data. Various rock types are very well visible on the data. In the sedimentary rocks, bedding, anticline, synclines etc. can be very well seen. It is possible to observe these due to differences in the spectral signature, vegetation, erosion and pattern etc. After the lithological units are differentiated, the structural mapping is done. In the structural mapping dips, faults etc. are mapped. Faults/ fractures are mapped through the lineament mapping. Lineaments are linear features visible on the remotely sensed data. These are visible due to sudden changes in the vegetation, spectral signatures, drainage etc. After the lineaments are mapped, the man made features e.g. canals, roads, transmission lines, fences etc. removed. The dykes are also mapped as lineaments. There may have good groundwater potential on one side of a dyke.

4.0 Conclusions

It is evident that the remote sensing and GIS techniques have limited but decisive roll to play in groundwater investigation, since sub surface features are manifested on the surface, in synoptic view much more information is revealed etc. The visible and infrared techniques are more in use presently.