HYDROGEOLOGICAL EVOLUTION OF PAGERU RIVER BASIN, INDIA: AN INTEGRATED APPROACH USING REMOTE SENSING, GEOPHYSICAL DATA

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Remote sensing data has been used to interpret the landforms in order to identify the groundwater prospect zones and also prepared Land use /Land cover classification map for agro-climatic zone planning. 112 geophysical surveys were conducted in basin area, based on depth to thickness, second layer and water level map we prepared groundwater potential zone map. The study reveals that large part of the area has poor groundwater potential. The productive groundwater zones are identified as isolated patches located in the central and northwestern parts of the region.

INTRODUCTION

Pageru river basin is located in Cuddapah district, Andhra Pradesh, India. Despite the fact that Cuddapah is one of the chronic drought prone districts of Rayalaseema region in Andhra Pradesh agriculture happens to be the main occupation requiring copious water supply. Unlike in the past surface water supplies are scarce or nil. Further owing to inadequate and erratic rainfall the groundwater has gone down to deeper levels and it is very difficult to select well locations by conventional geological methods. The aim of the study is to approach systematic hydrogeological studies of the basin to assess the groundwater potential zones.

STUDY AREA

Total area of the basin is 480 Km² lies between Lat 14° 39'04" and 14° 39' 51"N and Long 78°19'12" and 78°41'32"E The drainage pattern of the basin is dendritic in nature. The general climate of the basin is hot and semi-arid in nature. The River Basin receives an average annual rainfall of 581mm with significant seasonal variations.

GEOLOGY

The rock formations of the study area are classified as Cuddapah super group and Kurnool group. The oldest are Tadipatri formations belonging to the lower Cuddapah
super group essentially composed of slaty shales with interbedded thin layer of siliceous limestone, quartzite, and basic intrusive sills. The Tadipatri formations are overlain by the rocks of the Kurnool group, which include quartzite, limestone and shale (Fig.1). Alluvium of Holocene and recent age is more or less stratified deposit of gravel, sand, silt, clay occurring all along the course of the stream. The alluvium at the confluence near Putlampalli is found to comprise sand of variable thickness and is composed of sandy aquifers occurring the easternmost part of the study area.

**METHODOLOGY**

The Land use/Land cover classification was done with the help of IRS-1B, LISS-II FCC satellite images for both Kharif and Rabi seasons Geo coded at 1:50,000 scale by visual interpretation techniques and in conjunction with SOI topo sheets Nos. 57J/6,7,10 and11. The land use / land cover classification system developed by the National Remote Sensing Agency, Hyderabad, later modified on the suggestions made by Planning Commission of India has been adopted in the present study (NRSA [1]). The satellite data IRS-1B, LISS-II FCC on 1:50,000 scale of the area has been visually interpreted to delineate various geomorphic units based on image characteristics. The data is correlated with Survey of India topographical maps and verified during the field visits.

112 vertical electrical soundings (VES) were carried out at different locations in the study area using the Schlumberger method of electrode configuration. In the Schlumberger configuration the two outer current electrodes (AB) and the two inner potential electrodes (MN) are aligned in a straight line such that the distance between the potential electrodes and the current electrodes is always kept equal or less than one fifth of that of the current
electrodes at any stage during the probe. The apparent resistivity is measured at the centre of the electrode array. The electrode arrangement for the Schlumberger array is depicted in Fig. 2.

[Diagram of Schlumberger electrode arrangement]

The apparent resistivity $R$ is computed using the formula

$$\frac{(L/2)^2 - (b/2)^2}{b*R}$$

Where $L$ = distance between current electrodes (AB) 
$b$ = distance between potential electrodes (MN) and $R$ = $VI$
$I$ = potential difference between potential electrodes and the current flowing.

RESULTS AND DISCUSSIONS

Land use/land cover classification

The present classification is done with the help of IRS-1B Geo coded imageries on 1:50,000 scale by visual interpretation techniques. The detailed land use/land cover statistics of the Pageru river basin for the year 1996 is given in Table 1 (Sreedevi et al [2]).

<table>
<thead>
<tr>
<th>Land use / land cover classification</th>
<th>Area in Km$^2$</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-up land</td>
<td>4.88</td>
<td>1.02</td>
</tr>
<tr>
<td>Agricultural land</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kharif</td>
<td>349.98</td>
<td>72.92</td>
</tr>
<tr>
<td>Double crop</td>
<td>15.25</td>
<td>3.18</td>
</tr>
<tr>
<td>Plantation</td>
<td>2.25</td>
<td>0.46</td>
</tr>
<tr>
<td>Forest (Degraded/open forest)</td>
<td>19.13</td>
<td>3.99</td>
</tr>
<tr>
<td>Waste lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land with or without scrub</td>
<td>63.50</td>
<td>13.23</td>
</tr>
<tr>
<td>Barren rocky/stony waste/sheet rock area</td>
<td>4.13</td>
<td>0.86</td>
</tr>
<tr>
<td>Mining/industrial waste land</td>
<td>1.56</td>
<td>0.33</td>
</tr>
<tr>
<td>Water bodies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>River/stream</td>
<td>4.78</td>
<td>0.99</td>
</tr>
<tr>
<td>Tank</td>
<td>4.73</td>
<td>0.98</td>
</tr>
<tr>
<td>Others (Grass land/grazing land)</td>
<td>9.81</td>
<td>2.04</td>
</tr>
</tbody>
</table>
**Built-up land**

It is defined as an area occupied by human habitation developed due to non-agricultural use and which has a cover of buildings, transport, and communications, utilities in association with water, vegetation and vacant lands. Usually the built-up area lies in all types of terrain amid agricultural lands, forests and wastelands in association with road, rail and canal networks and artefacts. They appear distinctly in between the croplands of Kharif and Rabi seasons. As there are no urban areas, the rural settlements present in the study area cannot be identified in satellite imageries, as they are very small in extent comprising a total area of about 4.88 km², accounting 1.02 per cent to the study area.

**Agricultural land**

It is defined as the land primarily used for farming and for production of food, fibre, and other commercial and horticultural crops. It includes land under crops, plantations etc. The largest land use category in the basin is the irrigated area occupies 349.98 km², in Kharif season accounting for 72.92 per cent. The double-cropped area in the basin is 15.25 km², accounting for 3.18 per cent only.

**Plantations**

It is described as an area under agricultural tree crops planted adopting certain agricultural management techniques. These include coconut, citrus, and other horticultural nurseries. These occur on both uplands, and foothills and occasionally on river plains also. The area under plantations covers of about 2.25 km², accounting 0.46 per cent to the study area.

**Forest**

It is an area (within the notified forest boundary) bearing an association predominantly of trees and other vegetation types capable of producing timber and other forest products. These occur on the higher reaches of hill-slopes coinciding with zones of very high rainfall. *Degraded forest* It is described as a forest, where the vegetative density is less than 10-40 per cent of the canopy cover. It is the result of both biotic and abiotic influences. Degraded / open forests occur on mountain / hill slopes, isolated hills, uplands in association with different forest types and sub types within the notified forest area. The degraded / open forests cover an area of about 19.13 km², accounting 3.99 per cent to the study area.

**Waste lands**

This is described as degraded land which can be brought under vegetative cover with reasonable effort, and which is currently under utilized land deteriorating due to lack of appropriate water and soil management or on account of natural causes. Wastelands can result from inherent / imposed constraints such as location, environment, chemical and
physical properties of the soil and financial management constraints. Wastelands identified in the study area are described below.

**Land with or without scrub**
They occupy in relatively uplands or high ground with or without scrub. These lands are generally prone to degradation or erosion. These exclude hilly and mountainous terrain. Land with or without scrub occupies an area of about 63.50 km\(^2\), accounting 13.23 per cent to the study area.

**Barren / Rocky / Stony sheet rock area**
It is defined as the rock exposures of varying lithology often barren and devoid of soil cover and vegetation. They occur amid hill forests as openings or scattered as isolated exposures or loose fragments, boulders or as sheet rocks on plateaus and plains.
It occurs in steep hill slopes, crest, isolated hillocks, plateau and eroded plains in association with barren and exposed rocks. Barren rock outcrops cover an area of about 4.13 km\(^2\), accounting for 0.86 per cent to the study area.

**Mining / Industrial waste**
Mining industrial waste cover occupies a small area of about 1.56 km\(^2\), accounting 0.33 per cent for the basin area. The mining activity is noticed in the northern part of the study area.

**Water bodies**
This class comprises areas of surface water either impounded as ponds, lakes, and reservoirs or flowing bodies as streams, rivers, canals etc.

**River / Stream** It is a natural course of water flowing on the land surface along a definite channel. It may be seasonal or perennial. The river / streams occupy an area of about 4.78 km\(^2\), accounting for 0.99 per cent of the study area.

**Tanks** Tanks occur in lowlands of plains, uplands and valleys. The tanks occupy only 4.73 km\(^2\), in the basin area accounting for 0.98 per cent to the study area.

**Others**
It includes all those, which can be treated as miscellaneous because of their nature of occurrence, physical appearance and other characteristics. The others identified in the study area are described below.

**Grass Land / Grazing Land** It is an area of land covered with natural grass along with other vegetation, often grown for fodder to feed cattle and other animals. It occurs on uplands, hill slopes, foot slopes, (Piedmont zones) inland plains and close to river / stream beds in association with unirrigated and dry farming agricultural lands, lands fenced from cultivation, pasture grounds and meadows etc. The grassland / grazing land occupies an area of about 9.81 km\(^2\), accounting 2.04 per cent of the study area.
Hydrogeomorphological classification
The satellite data IRS-1B, LISS-II FCC on 1:50,000 scale of the area has been visually interpreted to delineate various geomorphic units based on image characteristics. The data is correlated with Survey of India topographical maps and verified during the field visits.

Generally, the different geomorphic units and associated landforms are classified by their geomorphic expression, relief, slope, and surface cover with soil or vegetation. The geomorphic map portrays the surface configuration, nature, and proportion of material and the intensities of the processes in operation. On the basis of image interpretation elements like tone, texture, size, shape, relief, pattern, association etc. various geomorphological units are identified. Various geomorphic units and landforms identified in the study area are presented in the map (Figure 3) and they are broadly discussed as fluvio-colluvial, denudational, structural, and depositional landforms as described below (Sreedevi et al [3]).

Fluvio-colluvial landforms
These are the landforms produced by fluvial processes. The fluvial landforms pertaining to groundwater management identified from the satellite imagery are mainly valley fills, floodplains and alluvial plains. Groundwater development is more promising in the floodplains, alluvial plains and valley fills that are associated with thick alluvium and weathered material to give high porosity and permeability. Only a small area is occupied by alluvial plains, flood plains and valley fills.
Denudational landforms
Denudational landforms are formed as a result of active processes of weathering, mass wasting and erosion caused by different exogenetic geomorphic agents such as water, glaciers, wind, etc. The landforms produced by the agents of denudation and identified from the satellite imagery are pediments and pediplains. Pediments are distributed in the central part and isolated pediments are present in the northern and western parts of the basin. Generally, they do not favour much infiltration and hence they are not favourable for groundwater exploration. Moderately weathered and shallow weathered pediplains are distributed all along the river course. As these geomorphic units exhibit low permeability characteristics, they can be classified as moderately favourable zones of groundwater.

Structural landforms
The geologic structure is a dominant controlling factor in the evolution of landforms and is reflected in them (Thornbury [4]). Geological structure has been used in the widest sense and includes not only rock types, folding and faulting, unconformity etc., but also the hardness, permeability and solubility of rocks. The presence of joints, bedding planes and solubility of rocks plays an important role in the evolution of landforms. The landforms of this type are formed not only due to lithological and structural control but also because of differential weathering and erosional processes. Structural landforms are identified from the satellite imagery are Mesa/butte, Cuesta hill, Structural hill and linear rides. These landforms are do not favour much infiltration, they are considered to be poor zones for groundwater exploitation.

Ves interpretations
Quantitative interpretation of the electrical resistivity data is done by considering the variation in the apparent resistivity for each electrode separation keeping the place of observation constant. Depicting different geological sections ideal standard curves for two, three, and four layers for various ratios of absolute resistivities are available as given by Orellana and Mooney [5] which can be fitted with the field curves for obtaining absolute resistivities for different layers. If the sub-surface consists of three layers with varying thickness there will be four possible combinations of their resistivities and corresponding sounding curves as given below.

\[
\begin{align*}
H - type & = \rho_1 > \rho_2 < \rho_3 \\
K - type & = \rho_1 < \rho_2 > \rho_3 \\
A - type & = \rho_1 < \rho_2 < \rho_3 \\
Q - type & = \rho_1 > \rho_2 > \rho_3
\end{align*}
\]

Various combinations make different four layer curves. The results of vertical electrical sounding interpretations were used to prepare the top layer contour map and the depth to basement map. Finally the groundwater potential map was prepared based on the two maps mentioned above and other available information.
**Groundwater Potential Zones**

Considering the assumptions, the resistivity survey holds good with homogeneity in the basin both vertically and laterally, the groundwater potential map has been prepared using the depth to bed rock map, water level fluctuation map, and the second layer thickness as shown in Figure 4. Groundwater potential map is classified into three areas as poor, moderate, and good zones. Very shallow depth to basement with out much thickness of the saturated zone is characteristic of the entire limestone area demarcated as the poor groundwater potential zone that occurs at the northern and southern border of the basin (Sreedevi et al [6]).

The moderate groundwater potential zone occurs in the central portion of the basin in between the northern and southern basin boundaries, which are occupied by poor zones in limestone and also at the north-eastern boundary. Almost the entire moderate zone is observed in shale only.

The productive zone named as good zone is observed mainly as three isolated patches one in the central portion and the other two at the northwestern portion of the basin in shale. These good zones are covered around Payasampalle at the centre and Kolavali and Vontigariipalle at the northwestern portion.

Thus geologically limestone is demarcated generally as poor zone and shale as intermediate and good zones. The limestone aquifer is shallow everywhere for want of secondary porosity and cavernous nature.

The groundwater potential map shall have a practical value as it will guide the farmers in locating well sites on one hand while it helps even if the locations are unfavourable in some areas in avoiding financial losses on the other.

![Figure 4. Groundwater potential map of the study area](image-url)
CONCLUSION

From land use/land cover map only 1.97 per cent area occupied by surface water bodies. 72.92 per cent area occupied by agricultural land and the double-cropped area is very limited occupying 3.18 per cent only. The total quantity of groundwater recharge per annum is estimated as 5434.5 ha.m, where as draft accounts for 4649.5 ha.m, with a net groundwater balance of 785 ha.m in the catchment area. Based on these studies the agricultural land available in the basin area is more, the total land could not be brought into cultivation due meager surface and groundwater resources present in the catchment area.

The various geomorphic units are classified as favourable, moderately favourable and poor zones of groundwater. Groundwater development is promising in the floodplains, alluvial plains and valley fills that are associated with thick alluvium and weathered material that has high porosity and permeability characteristics. Only a small area is occupied by these landforms, and hence favourable zones of groundwater are very limited in the basin area. A large part of the area is occupied by pediments, pediplains, structural hills, mesas and buttes, which do not favour much infiltration and hence are generally not favourable for groundwater exploration.

Based on the resistivity surveys conducted in the basin area, the groundwater potential producing zones are identified. The study reveals that a large part of the area has poor groundwater producing potential. The productive groundwater zones are identified as isolated patches located in the central and northwestern parts of the region. Generally, the limestone and quartzite areas are demarcated as poor zones whereas the areas covered with shale have moderate to good groundwater potential. In some areas the limestone is at a shallow depth and productive because of its cavernous nature at this depth.

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REFERENCES


