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Selection of groundwater potential zones in and around Madhurawada Dome, Visakhapatnam District - A GIS approach

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ABSTRACT
Hydrogeomorphological mapping coupled with hydrogeological investigations has been carried out to evaluate groundwater potential zones in and around Madhurawada. The study area, geologically a dome, is spread over 190 km^2 in Greater Visakhapatnam Municipal Corporation (GVMC) in Visakhapatnam District, Andhra Pradesh. Thematic layers of drainage, geology, geomorphology, lineaments and well inventory have been generated by using toposheet (No.65O/5), GSI geology map, IRS-ID, LISS-III, April, 2004 digital data. Inventory of twenty four dug wells during pre-monsoon and post-monsoon periods of 2008 reveals that the water table fluctuates from 1.5 to 12 m bgl. Four rock types are observed, khondalite is the major type and others are later intrusives into the country rock. Ten hydrogeomorphic units are delineated on satellite data, out of which five are recharge zones and five are run-off zones. The five recharge zones, pediplain shallow, pediplain moderate, pediplain deep, valley fill shallow and piedmont slope have been intersected with geology in ArcGIS-9.1 environment. A buffer zone has been generated to lineament map to establish its influence on groundwater occurrence and distribution. The groundwater potential zones identified through GIS analysis have been classified in to five categories from very low to high.

INTRODUCTION

The study area, the Madhurawada dome abutting the Bay of Bengal on the East is a part of Visakhapatnam District, Andhra Pradesh. The area spreading over 190 km^{2}lies in Peddagedda river basin (181 km^2) and Maddigedda rivulet (11.19 km^2) is located in between 19^o 78′ 08" and 19^o 78" 44.21" N lat and 73^o 51′ 42.78" and 75^o 63" 54.60" E long (Fig.1). Cultivation is the major landuse near the river mouth and upstream part of Peddagedda river whereas; Maddigedda river basin has only built-up area. As per 2001 Census, the area has a population of 52,000 with a decennial growth rate of 22.44%. Hence, the population for the year 2008 is estimated at 61,000. The annual rainfall in the area varies from 1000 mm to 1200 mm. Erratic precipitation of rainfall in recent years (2001 to 2004) in addition to insufficient surface water bodies has led to severe drought conditions. This has resulted in increasing exploitation of groundwater. Hence, this investigation is undertaken to identify groundwater potential zones to tide over water scarcity. Out of the many villages in study area well inventory has been undertaken in comparative to the thickly populated villages Sontyam, Marikavalasa and Mangamaripeta, etc.

DATA USED

In this study, toposheet of 1:50,000, geology map published by GSI (District map on Geology and Minerals, 2001) and IRS-ID-LISS-III of April, 2004 digital data have been used. On screen digitization has been followed to delineate ten units of denudational and fluvial landforms. Drainage pattern extracted from toposheet, and major and minor lineaments as confirmed and inferred, have been drawn on satellite image with drainage as control on toposheet. Boundaries and extensions of lithological units have been redrawn in geology map using satellite

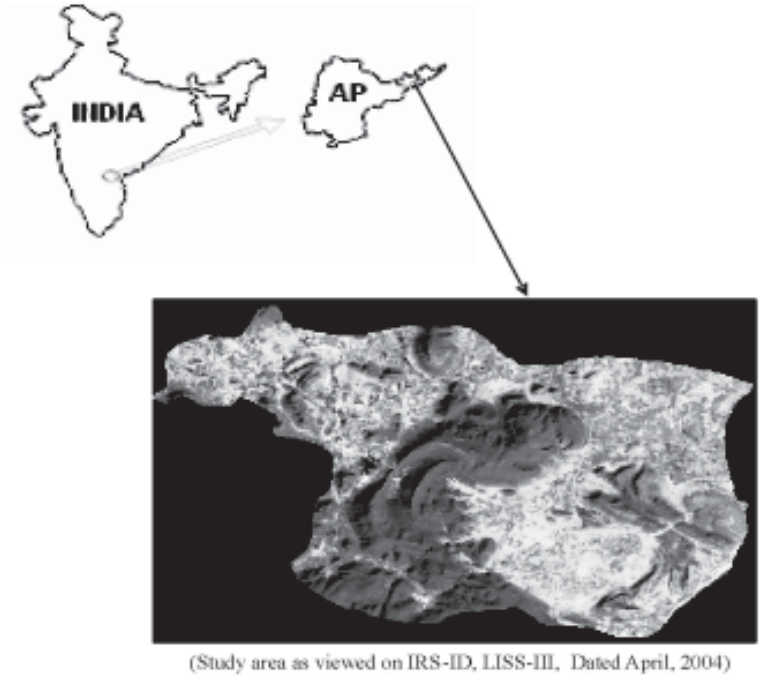

Figure 1. Location map of the study area.

image. The two charnockite hillocks in the region have almost reached ground level owing to quarrying. These were identified on satellite image as bluish to light black tint.

RESULTS AND DISCUSSION

Drainage pattern

The area has moderate to high drainage density. Peddagedda river has two tributaries, Marikavalasagedda and Chittagedda. Different drainage patterns such as dendritic, sub-dendritic, parallel, radial and annular are prominently seen. Hills are characterized by radial and annular type drainages over the Madhurawada dome (Fig.2).

Peddagedda river has attained 6th order (Strahler 1952) before it terminates into the Bay of Bengal. It is a minor category (Rao 1970) non-perennial river with a drainage area of 181 km^2. The storage capacity of the Gambhiram reservoir constructed across the river to supply water to the people of Visakhapatnam has been reduced to around 40% owing to siltation (Jagadeeswara Rao, Harikrishna & Suryaprakasa Rao 2006). A small non-perennial Maddigedda rivulet with an area of 11.19 km^2 flows in the southeast of Madhurawada dome. The major non-perennial streams have been delineated as lineaments as confirmed and inferred lineaments as per the norms of Rajiv Gandhi National Drinking Water Mission (1998). This has further been supported by toposheet and satellite imagery studies. Major streams flowing through narrow valleys deposited considerable amount of denuded material which can be delineated as valley fill shallow landform. The spatial arrangement of streams with structural control can act as conduit for groundwater recharge and storage at places.

Geological set-up

The area is covered with khondalite suite of rocks belonging to Archaean age. Charnockite rock occurs as intrusive bodies and acts as dykes in the area (Fig.3). General strike of the rocks is NNE-SSW; however, local variations are identified at places (Sriramadas 1964; Chetty et al., 2002, Jagadeeswara Rao, Harikrishna & Suryaaprakasa Rao 2006).

The charnockite hillocks being quarried appear as light black to cyan color on satellite image. There is a slight shift of small hillocks in GSI map in comparision with satellite imagery. A small spatial discrepancy has been observed in the position of hillocks, when the GSI map is compared with the satellite imagery. Parent khondalite rock, intrusive rock bodies, dome, denudational and fluvial activity made the area a separate entity in terms of groundwater occurrence.

Hills contain thick veneer of soil cover and support

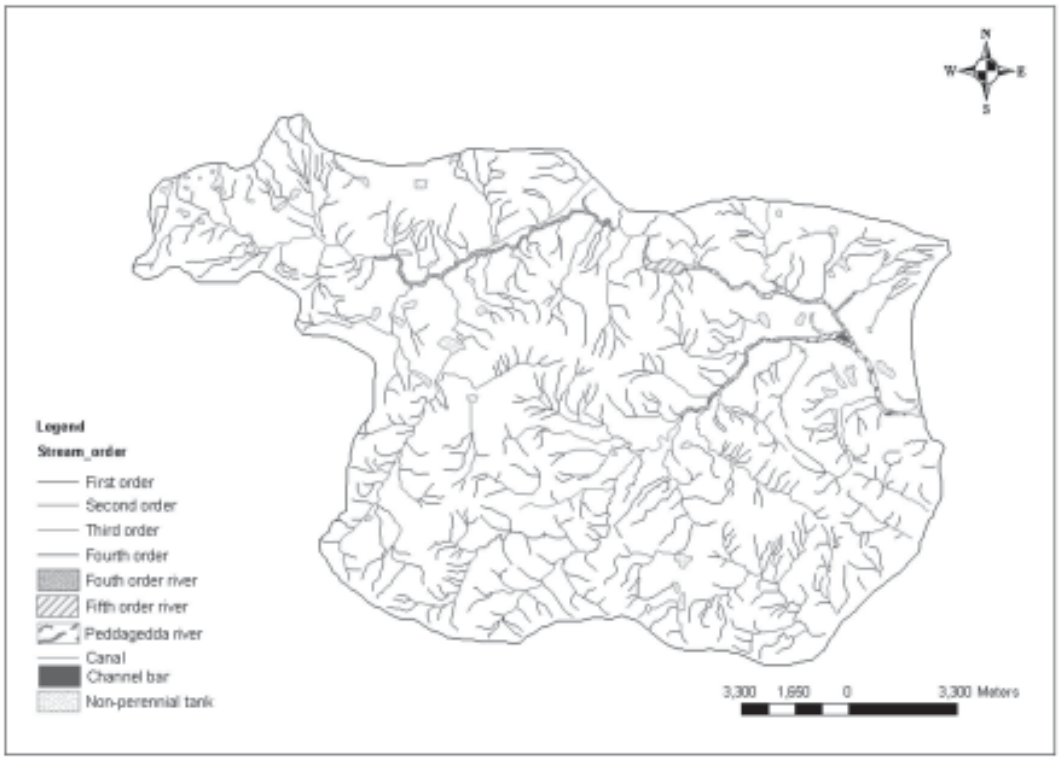

Figure 2. Drainage pattern of the study area.

Table 1. Geological succession and groundwater prospects

Age	Rock types	Groundwater prospects
Recent	Coastal alluvium, river alluvium and residual soils	Shallow fresh water table with high groundwater potential
Sub-recent	Laterite and Laterite capping	Low groundwater potential
Archaeans	Khondalite suite of rocks intruded by charnockite and quartzite	Crystallite hard rocks, low groundwater potential

semi-evergreen deciduous forest. Downstream of Gambhiram reservoir has recent deposits of river alluvium. The geological succession and groundwater prospects of the study area are given in Table 1.

Geomorphology and lineaments

Geomorphological studies coupled with hydrogeological and structure/lineaments have been proved to be very effective to locate groundwater potential zones (Bahuguna et al., 2003; Jagadeeswara Rao, Harikrishna & Suryaprakasa Rao 2004).

Geomorphology and lineament maps of the area have been generated following the standard visual interpretation techniques on satellite image. Denudational and fluvial landforms have been delineated; of these, structural hills, denudational hills, residual hills, inselbergs and pediment inselberg complexes are the run-off zones. They cover an area of 57.35 km^2. Pediplain shallow, pediplain moderate, pediplain deep, piedmont slope and valley fill shallow are suitable areas for infiltration (recharge zones) and they collectively make up about 134.65 km^2 (Fig.4). It has been observed from the well inventory that the thickness of weathered zone is more than 12 meters in PPD, while it is 12 meters in PPS and PPM respectively. Shallow groundwater table is the characteristic of Kapula Uppada (1.5 m bgl) Marikavalasa (1.8 m bgl) and Mangamaripeta (2.7 m bgl) villages. In the vicinity of these villages, paddy

Figure 3. Geology and geological structure of the study area.

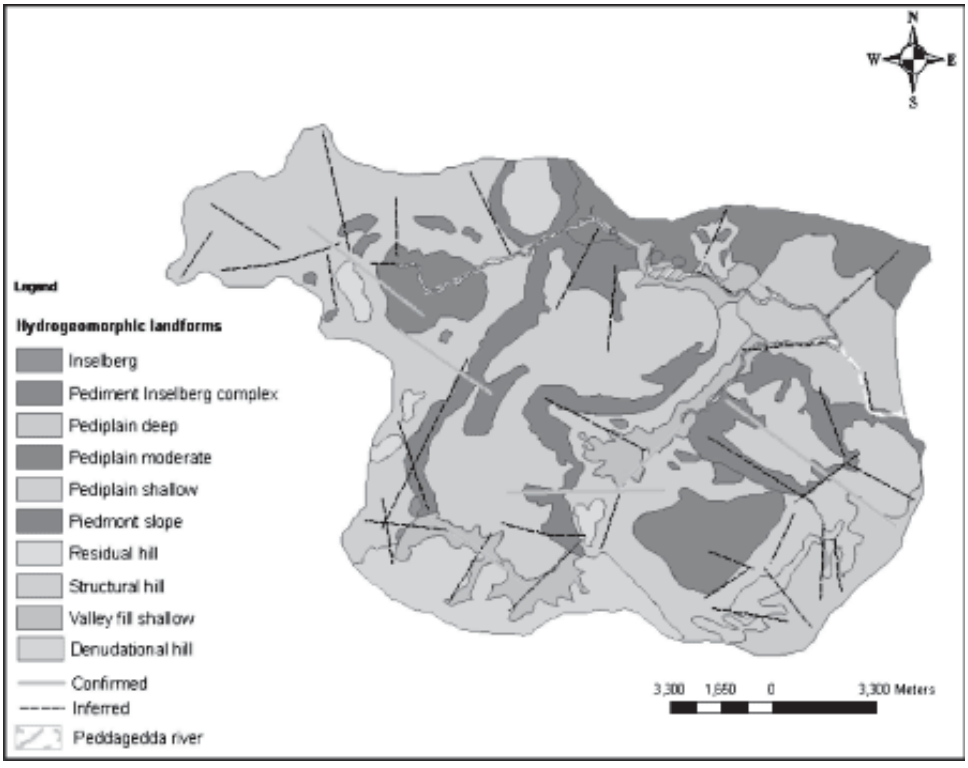

Figure 4. Gemorphology and lineaments of the study area.

Table 2. Area under each geomorphic unit

S.No	Geomorphic unit	Name of the village	Area under each category	Landuse/ landcover
1	Piedmont slope	Kommadi, Boravainipalem	18.033	Gullied/plantation
2	Valley fill shallow	Dabbanda, Chemudupalem	10.05	Gullied/plantation
3	Pediplain shallow	Erravanipalem, Kottaparadesipalem	41.5	Single/ Double crop area
4	Pediplain moderate	Sontyam, Madhurawada	13.66	Double crop area
5	Pediplain deep	Mangamaripeta, Boyapalem	15.38	Double crop area

is in cultivation in kharif and rabi. Area under each category of landform is given in Table 2.

Maps of confirmed and inferred lineaments generated in the present investigation (Fig.4). High lineament density over hilly terrain and moderate to low lineament density over the plains. Aerial photographs and satellite imageries in structural analysis have been proved to be affective for lineament mapping (Prudhvi Raju & Vaidhyanadhan 1981). Lineaments with criss-cross nature generally show a very high groundwater potential. If the lineaments extend down to the plains and are fed with river system, the areas become potential zones for groundwater exploitation (Sanjay Raj & Sinha 1989).

Well inventory

Groundwater levels have been measured in twenty four dug wells during pre-monsoon and post-monsoon periods in 2008. Location of wells has been obtained with handheld GPS (Mio) instrument and plotted on map with its coordinates in ArcGIS (9.1) environment. The water table occurs in unconfined and semiconfined conditions. Groundwater level contour map has been generated in ArcGIS environment (Fig.5). The area has very shallow (1.5 m bgl) to very deep (12.2 m bgl) water table.

The spatial distribution of groundwater is not uniform, the downstream of Gambhiram reservoir area has shallow water table, whereas other areas have medium to deep water table configuration. In Sontyam village, the water table varies from 4.35 m bgl to 12.2 m bgl (Table 3) within a distance of 2 kilometers because of the presence of shallow hard rock as a barrier. Deep water table occurs adjacent to the foot hill.

Groundwater potential zones

Thematic maps of geology, geomorphology and lineament are used in GIS analysis. The country rock khondalite has been selected for location of groundwater potential zones, other intrusive rocks have not been considered as they act as dykes in the area. All landforms indicative of recharge zones are selected. A buffer zone of 500 meters and 200 meters has been assigned to confirmed and inferred lineaments respectively. It is assumed that these lineaments may augment groundwater upto the respective distances. All these coverages were intersected in ArcGIS-9.1 environment to get final groundwater potential zones. The groundwater potential zones are classified into 5 categories - 1) low, 2) medium, 3) high medium, 4) high and 5) very high, on the basis of geomorphological units in the area. The villages located on these zones and their major land use/land covers are given in Table 4.

Groundwater recharge zones cover an area of 135 km^2. Area under each geomorphic zone is shown in Figure 6. Pediplain shallow covers the upstream of Peddagedda river, whereas pediplain deep covers downstream of Gambhiram reservoir. Thus landforms of fluvial and denudational origin have direct control over groundwater occurrence and distribution. Interception of lineaments with the groundwater potential zones is highly potential for groundwater exploration. Lineaments, landform, rock type and

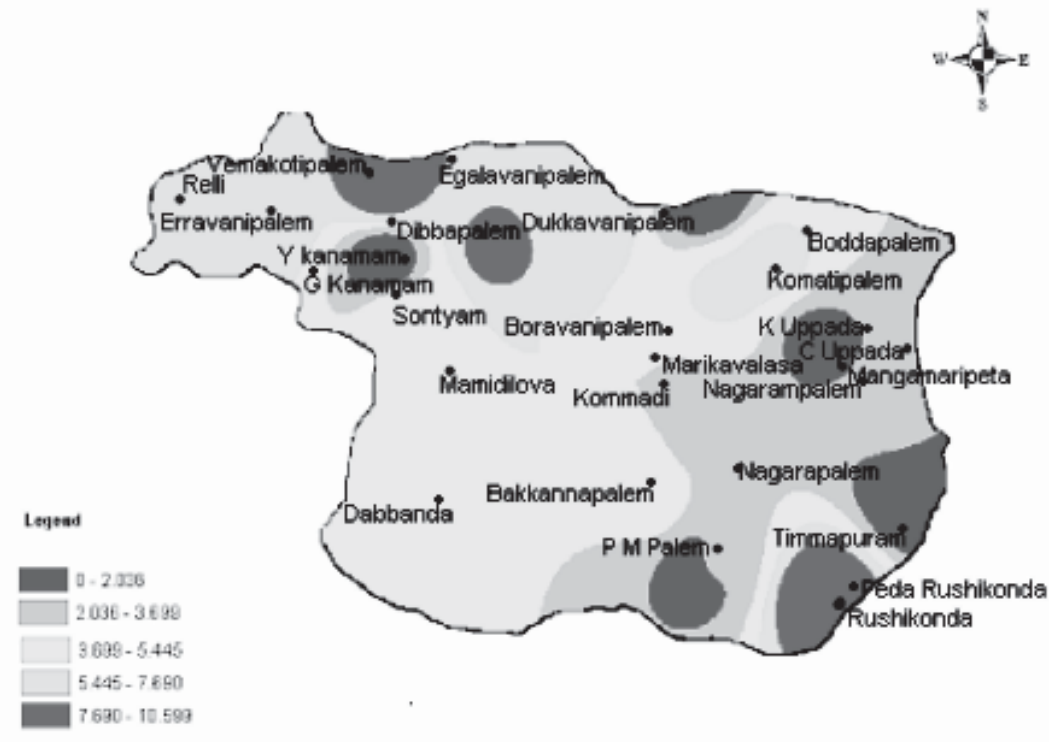

Figure 5. Groundwater fluctuation map of the study area.

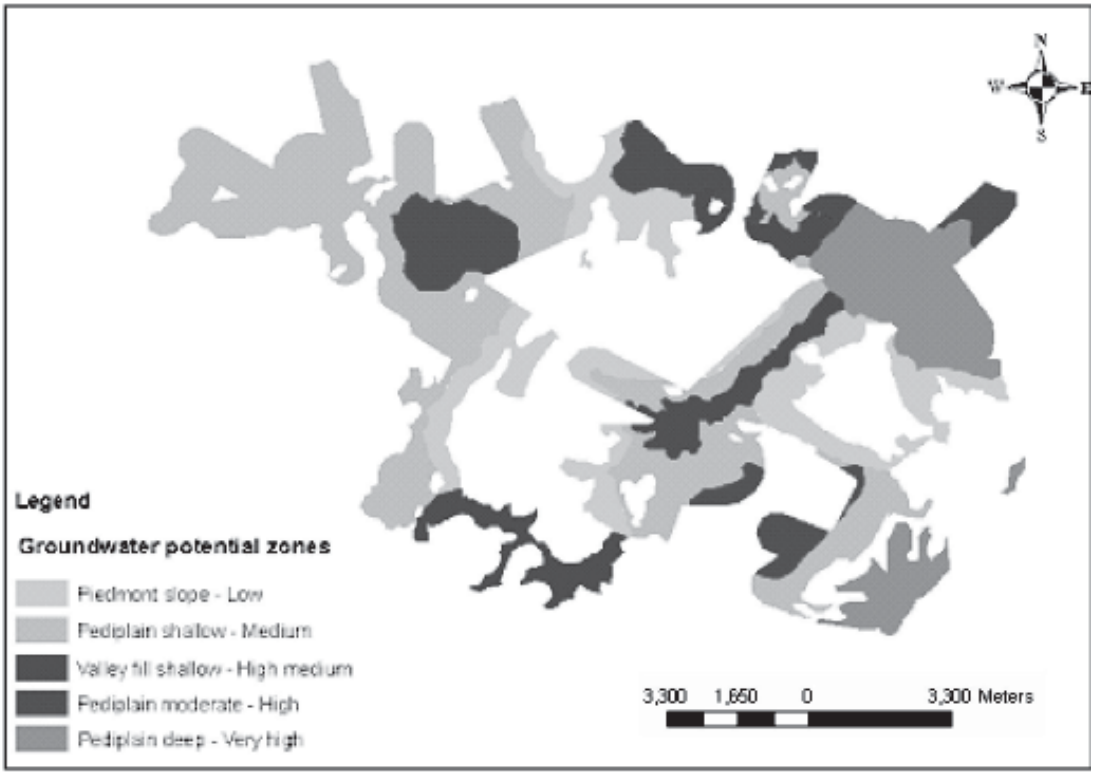

Figure 6. Groundwater potential zones in the study area.

Table.3. Wellinventory of the study area

S.No	Name of the village	Type of well	Dia (Mts)	Total Depth (Mts)	Depth to water level (M bgl)	Fluctuation (M bgl)	Taste	Geo-morphic unit	Lineament	Aquifer material	Geological Horizon
1	Rushikonda	Dug	2	12	10.60	8.15	Potable	Pediplain deep	Criss-cross	Weathered rock	Khondalite
2	Peda Rushikonda	Dug	3	10	6.55	0.7	Potable	Pediplain deep	Criss-cross	Weathered rock	Khondalite
3	Mangamaripeta	Dug	4	4.5	2.70	1.70	Potable	Pediplain deep	Confirmed	River deposition	Khondalite
4	Boyapalem (Gambhiram)	Dug	1.5	7.0	5.90	0.95	Potable	Pediplain deep	Confirmed	Down stream of reservoir	Khondalite
5	Boddapalem	Dug	5	10.5	9.70	3.35	Non-potable	Pediplain Moderate	Criss-cross	Weathered rock	Khondalite
6	Prakruthivanipalem	Dug	5	9.40	6.60	6.5	Potable	Pediplain Moderate	Criss-cross	Weathered rock	Khondalite
7	Sontyam	Dug	5	9.5	4.35	Ground level	Potable	Pediplain Moderate	Criss-cross	Weathered rock	Khondalite
8	Gonthinavanipalem	Dug	3	6	4.50	2.65	Potable	Pediplain shallow	Criss-cross	Weathered rock	Khondalite
9	Vemakotipalem	Dug	3.5	11.5	9.70	6.8	Potable	Pediplain shallow	Criss-cross	Weathered rock	Khondalite
10	Yet a Kanamam	Dug	3	8.0	6.20	2.5	Potable	Pediplain Moderate	Criss-cross	Weathered rock	Khondalite
11	Dabbanda	Dug	3	6.5	5	3	Potable	Pediplain shallow	Criss-cross	Weathered rock	Khondalite
12	Marikavalasa	Dug	3	5.6	2.80	1.8	Potable	Valley fill shallow	Inferred	Weathered rock	Khondalite
13	Kommadi	Dug	1	5.5	4.60	2.3	Potable	Valley fill shallow	Inferred	Weathered rock	Khondalite
14	Bakkannapalem	Dug	1	6	4.20	1.57	Potable	Valley fill shallow	Confirmed	Weathered rock	Khondalite
15	Mithilapuri vuda colony	Dug	1	12	3.3	2.0	Potable	Pediplain Moderate	Criss-cross	Weathered rock	Khondalite – Dome
16	Dukkavanipalem	Dug	2	10	6.10	2.9	Potable	Pediplain shallow	Criss-cross	Weathered rock	Khondalite
17	Kapula Uppada	Dug	3	10	1.5	Ground level	Potable	Pediplain deep	Inferred	Weathered rock	Khondalite
18	Eegalavani palem	Dug	3	7	DRY	-	Potable	Pediplain Moderate	Criss-cross	Weathered rock	Quartzite-hillock
19	Mindivanipalem	Dug	3	12.5	8.3	4	Potable	Pediplain shallow	Criss-cross	Weathered rock	Khondalite
20	Sontyam	Dug	1	13	12.2	5	Potable	Pediplain Moderate	Criss-cross	Weathered rock	Khondalite

Table 4. Groundwater potential zones in the study area

S.No	Geomorphic Unit (landform)	Area under each category (km^2)	Percent area of each category
	Run-off zones		
1	Structural hills	40.70	21.399
2	Denudational hill	13.11	6.893
3	Residual hill	2.163	1.137
4	Pediment inselberg complex	2.066	1.086
5	Inselberg	3.17	1.667
	Infiltration zones		
6	Pediplain deep	20.83	10.952
7	Pediplain moderate	24.12	12.681
8	Pediplain shallow	57.22	30.084
9	Piedmont slope	19.00	9.989
10	Valley fi ll shallow	7.82	4.111

weathered zone conditions are the major controlling parameters in assessment of groundwater potential zones (Obi Reddy et al., 2000). Groundwater is being extensively used for irrigation in pediplain shallow and pediplain deep. Madhurawada dome has been developing built-up area and therefore groundwater is the only source for domestic use. GVMC is supplying water to this area from deep bore wells.

CONCLUSIONS

The study area, the Madhurawada dome, is a part of Visakhapatnam, one of the fastest growing cities in India. Groundwater is being extensively used to cater to the needs of the people. Groundwater withdrawal is increasing year after year due to very erratic rainfall and insufficient surface water bodies resulting, in the drying-up of dug and bore wells. To understand the groundwater regime, well inventory data have been collected in pre-monsoon and post-monsoon periods. Water table contour map shows very shallow, moderate and very deep water table configuration with a fluctuation of 1.5 to 12 m bgl. Groundwater potential and water table fluctuation are in agreement with the denudational and fluviatile landforms of Peddagedda river. Ten hydrogeomorphological units are subdivided into run-off and recharge zones. Thus, groundwater exploration is possible from the units of pediplain deep, pediplain moderate, pediplain shallow, valley fill shallow and piedmont slope in the order of abundance. Using GIS technique, different groundwater potential zones were identified in recharge zones of fluvial and denudational landforms. However, large extraction of groundwater in PPD in river mouth leads to sea water intrusion. Keeping this in view, a proper groundwater management should be adopted to utilize groundwater in a sustainable manner.

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