International Journal of Civil Engineering (IJCE)
ISSN: 2278-9987
Vol.1, Issue 2 Nov 2012 25-34

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

STUDY OF GROUNDWATER LEVEL PROFILE IN AN UNCONFINED AQUIFER: CASE STUDY OF NAGPUR URBAN AREA, CENTRAL INDIA

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ABSTRACT

Groundwater flow analysis in an unconfined aquifer has received more and more attention by hydrologists for the prediction of drawdown patterns of the water table in an aquifer. The increase in Irrigational, Industrial and Domestic draft worldwide made mandatory to study the groundwater flow and its variable characteristics. Remote Sensing (RS) System and Geographic Information System (GIS) have been used as technological application for generation of various thematic maps. In this study, attempt has been made to analyze variation groundwater profile in a shallow unconfined aquifer in accordance with the ground surface topography. The profiles were generated for five sections in the study area using the GIS tool Overlay of the Surface contours and the groundwater level contours. The sections were selected on the basis of Hydrogeological map of the study area. In second part the weathering extent of five areas rock samples were tested for water Absorption in soil laboratory.

KEYWORDS: Groundwater Reserve, Groundwater, Hydrologists, Aquifer

INTRODUCTION

Groundwater as a precious natural resource which is widely distributed on the Earth than any other natural resource is dynamic in nature. The occurrence of the groundwater is in the saturated zone of variable thickness and depth, below the Earth's surface. A large underground reservoir exists where the part of precipitation in the form of subsurface water is stored in cracks and pores in existing rocks and unconsolidated crystal layers. In hard rock terrain it is eventually limited groundwater reserves and its occurrence is essentially confined to fractures and weathered zones. Groundwater occurrence, origin and movement are directly dependent upon the geological formation like Lithology, thickness, soil and structural parameters of specific areas. Thus, understanding the groundwater dynamic the study of Geology, Geomorphology and Lineaments of the area, this controls the terrain characteristics.

The present study focuses on the occurrence of groundwater in an unconfined zone, relating with the surface topography in study area of urban Nagpur city, Maharashtra, India using the RS-GIS applications. Secondly, the experimental results of water absorption of weathered rock samples received from parts of the city area correlated with the weathering extent of that area.

Study Area

Nagpur city as a typical study area has been chosen for the present study. It is the tropical city, centrally located in India (Figure 1). The Nagpur City lies in the 21°5' N and 79°5' E having an area of about 217.565 km^2. A number of reasons can be ascribed to select Nagpur as most suitable for this kind of study. These can be enumerated as below:

- The city is situated at an altitude of 290 meters above the mean sea level, rises up to 350 meters in South-west, West and South-west part of the city.
- Nag and Pioli rivers flows towards East of the city and joins Kanhan river.

- Nagpur town is developed on basalt rocks and the soil type is black cotton soil.
- It is a city, which does not show vertical growth but is recording a horizontal 'Radial' growth.
- The climatic conditions in this region are dry and semi-humid type. The summer extreme temperature rises up to 48^{o} C in the month of May.
- The rain in Nagpur is heavily dominated by the south-west monsoon winds where the average annual rainfall receives of about 1205 mm. However the winter is chilling with temperature up to 11^{o} C or below.
- The 2011 census figures population of the city about 23, 98,165.

Figure 1: The location of Nagpur metropolitan city

Objective of the study

a) To establish relationship of between the Groundwater level profile and the surface topography in a saturated unconfined zone.

b) To evaluate weathering extent at present from the laboratory analysis of the weathered rock samples for water absorption test specific to different parts of the study area.

Methodology

In the present study Resourcesat-1(IRS-P6-LISS IV) data acquired of 7th March, 2010 (Figure 2), Survey of India toposheets and Geological map of India (GSI,) were used. Various thematic maps like base map, geology, Hydrogeology, land use/ land cover, Surface contour map, Groundwater level contour were prepared using ArcGIS 9.1.

The contour map is generated for the study area from the 1 m interval toposheets. Also, groundwater level contour map for May, 2003 is generated from the available water levels at the 74 different observation well points (Jain P.K., 2004) within the study area. Five critical sections were selected such passing from the different geological formations and water bodies and the ground surface profile is generated in AutoCAD-07.

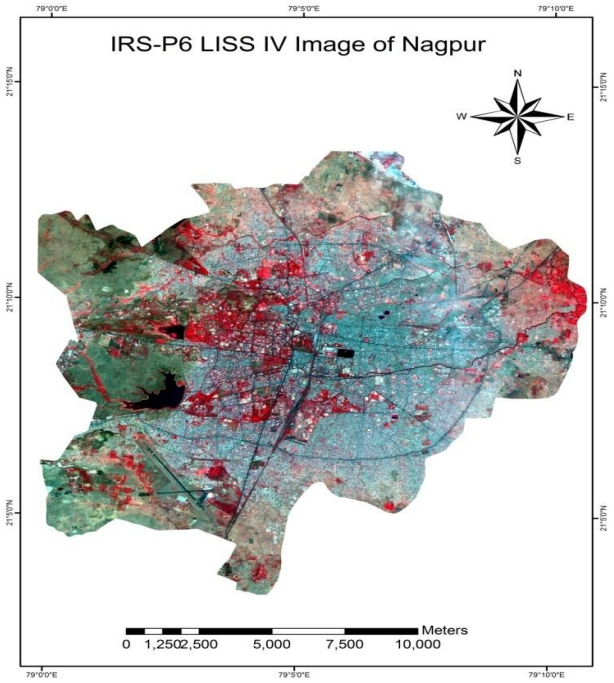

Figure 2: IRS- P6 LISS IV Image of Nagpur City (Resolution 1 m)

GEOLOGICAL FORMATIONS

The major geological formations found in the study area are detained follows:

1. **Gondwana Formation**: These are sedimentary rocks of Lower to Upper Cretaceous occupying the northern portion of the Nagpur City. These rocks are represented by Kamthi and Talchir formations. The Kamthi formation consists of alternate layer of Sandstone and Shale and forms a potential groundwater aquifer. Talchir occupies very limited area in the northern part Comprises of alternate layers of Shale and Sandstone and exposed at some places.

2. **Basaltic Lava Flow**: The horizontal basaltic lava flows (Deccan Traps) of upper cretaceous to lower eocene age occupies the major portion in the western and southern part of the city. These flows are generally separated by Intertrappean beds. The thickness of these formations varies from few meters to more than 200 m. The thickness of individual flow varies from 11-24 m. Basalt which renders it poor aquifer characteristics, however, the presence of the fractures and joints turn this unit into potential aquifer.

3. **Lameta**: This formation of upper cretaceous is overlain by the Gondwana group of rocks and underlain by the basaltic formation in the area. The lameta occurs as narrow belt in the city in the central part and further southeast of the south eastern boundary. These formations comprise of sandstone, varigated clays, limestone and cherty limestone with thickness varying from 4-10 m. These formation forms very poor aquifer in the city.

4. **Archean**: These rocks are mainly of igneous origin and formed due to cooling of Magma below the surface. These are coarse grained formation without primary porosity. On metamorphism it has converted to Schists and Gneisses. The main rock of this kind found are Granite, Granitic gneisses, Schist, pegmatite etc. in the north-east and East parts of the city. The water bearing capacity of these formations depends upon the intensity of weathering, joints, factures and thickness of sheared zones.

5. **Alluvium**: The alluvium of recent age occurs in very limited extent along the Pioli river around Nara and Nari in the city area. It is comprised of sand, silt, clay, kankar and its admixtures. The thickness of alluvium found in the city is less than 20 m but the granular zone found beneath forms a very potential aquifer in the city area.

The different geological formations (Figure 3) and the respective area occupied (Table 1) in the metropolitan boundary of the Nagpur city is tabulated below.

Table 1: Geological Area of Different Formation in Nagpur City

Sr. no.	Formation	Area(km^2)
1	Alluvium	4.242
2	Lameta	13.756
3	Gondwana	18.63
4	Archean	49.635
5	Basalt	131.302
	Total Area	**217.565**

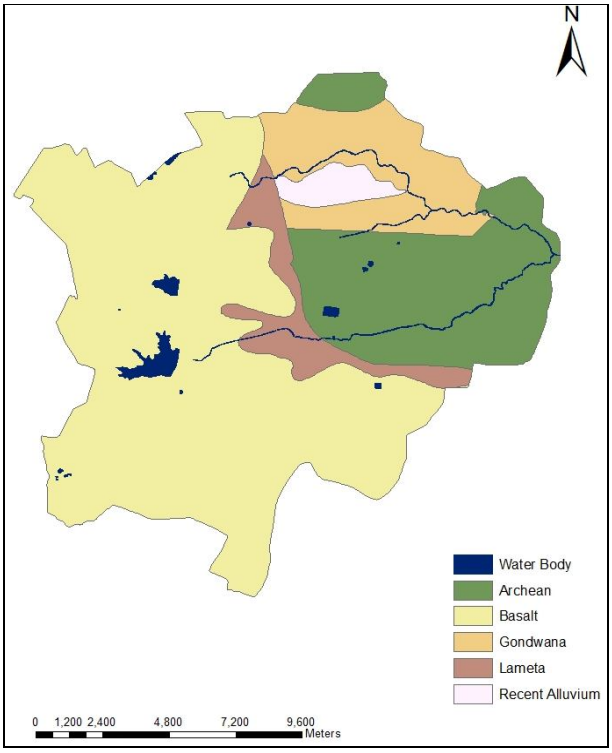

Figure 3: Hydrogeology Map of the Nagpur City

Aquifers in the Study Area

On the basis of the hydrogeological set up, the Nagpur city area is divided into four aquifer domains (Shastry B.V. 1996).

1. Single aquifer domain- Precambrain Schists and Gneisses. The groundwater occurs in the weathered mantle forming shallow unconfined aquifer.
2. Double aquifer domain- Lameta sediments at the surface are underlain by the Precambrain crystallines. The upper Lameta and the weathered top of the underlying Precambrain from a single zone formed by the juxtaposition of two aquifers.
3. Multi aquifer (Gondwana) domain- Characterized by the occurrence of the Gondwana sediments over the Precambrain basement. At top a shallowest aquifer of the water table type with shallow flow system.
4. Multi aquifer (Deccan Trap) domain- The domain is characterized by the Basaltic Deccan Trap flows. Intertrappean sediments at few places and Lameta sediments below the flows. The topmost aquifer of unconfined type is formed by the weathered mantle and is shallow flow system. Below this, confined aquifer with intermediate to deep flow systems exists.

The LU/LC in the vicinity of the study area (Figure 4) is a typical urban spreading example. A radial growth pattern is observed here. The residential area can be subdivided into three

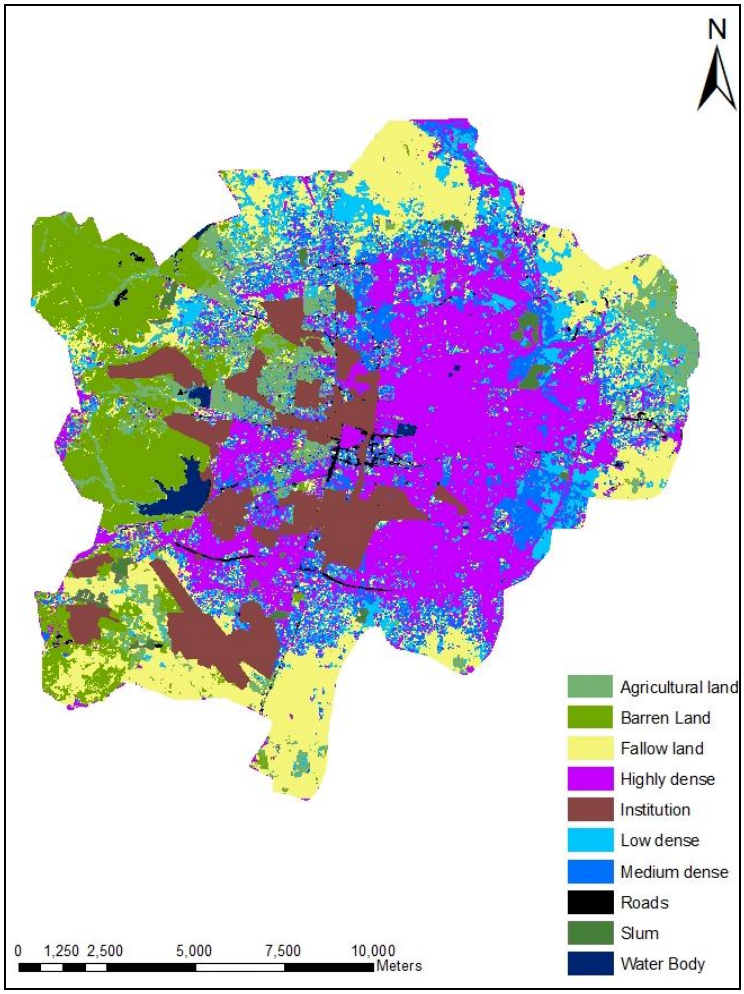

Figure 4: Land Use/ Land Cover Map of the Nagpur City

groups as High dense, Medium dense and Low dense which is widely distributed over entire area. The east part is basically the catchment area of the Ambazari and Futala lakes which comes under the Barren land category. The other categories and the respective area consumed is tabulated below:

Table 2: LU/LC Classification in the Study Area (2010)

Sr. No	Land use /Land cover Class	Total Area (km^2)
1	High dense residential area	22.135
2	Medium dense residential area	30.08
3	Low dense residential area	18.48
4	Crop Land	45.52
5	Fallow Land	27.62
6	Waste Land	16.70
7	Public-semi public, govt offices	14.93
8	Industrial Area	4.22
9	Commercial Area	5.08
10	Public Utility	6.90
11	Water Body	5.36
12	Open Ground	4.49
13	Garden	0.98
14	Institutional Area	3.04
15	Slum Area	2.44

RESULTS AND DISCUSSIONS

The ultimate objective of the study is to find relationship between the surface topography and the groundwater level in an unconfined zone. The GIS application served as an advantage for the present study. The overlay operation of the various thematic layers is possible in the GIS techniques. At the initial level the groundwater level map (Figure 4) has been prepared.

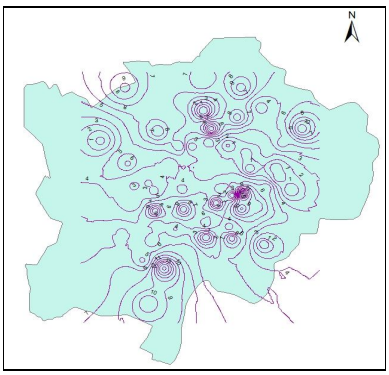

Figure 5: Groundwater Level Contour (May, 2003) of the Nagpur City

Generation of Profiles

The five sections selected across the city (figure 6) and the groundwater level profile and the surface topography profile generated are shown below. Figure 7,8,9 and 10 are the profiles drawn along selected section lines showing lithology vs. groundwater profile.

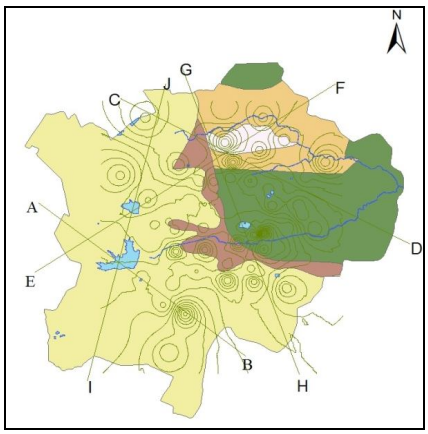

Figure 6: Sections along the Study Area

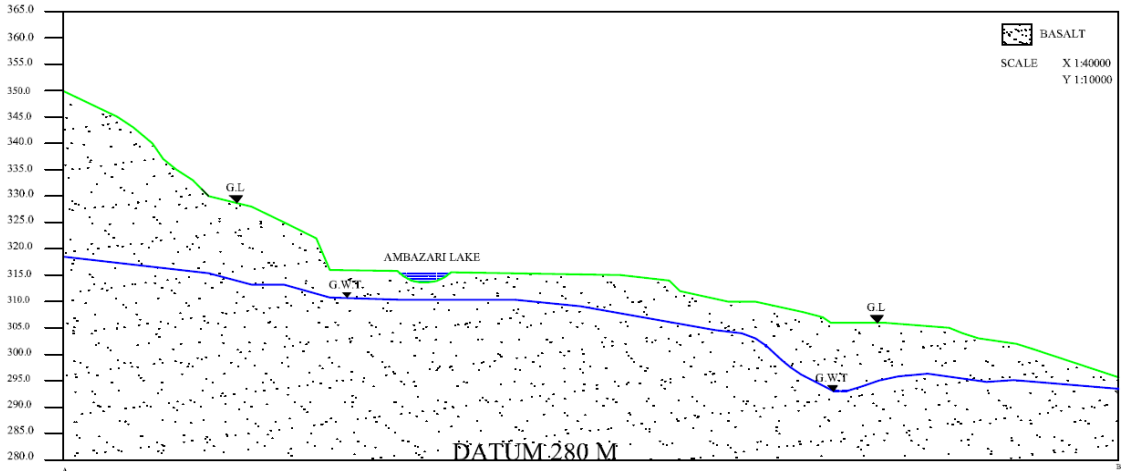

Figure 7: Section along A-B

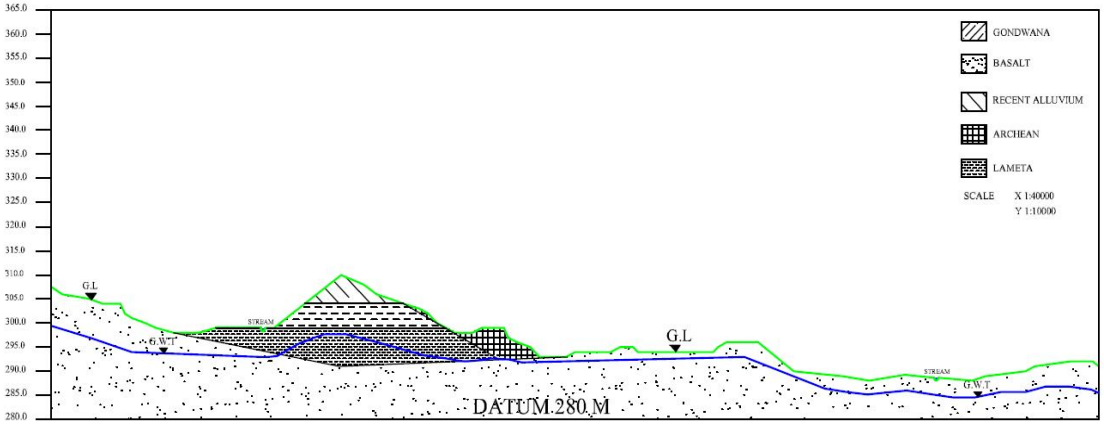

Figure 8: Section along C-D

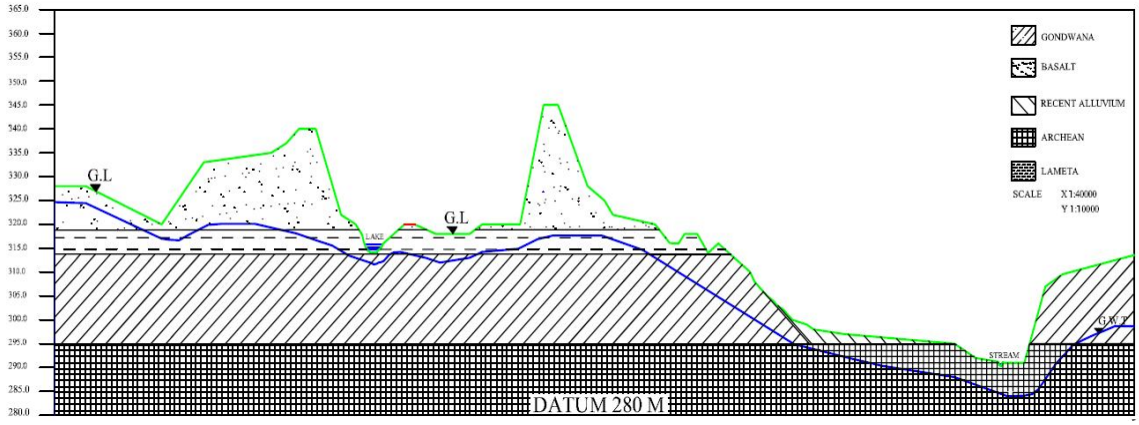

Figure 9: Section along E-F

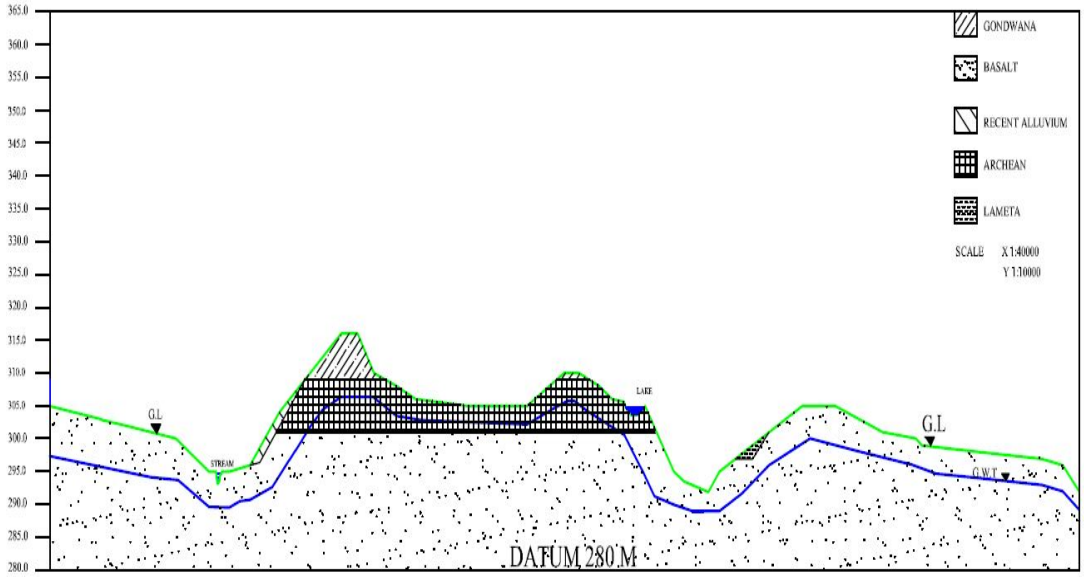

Figure 10: Section along G-H

Experimental Results

Weathering of the rock material is of two types. Any process that exerts a stress on a rock that eventually causes it to break into smaller fragments is a type of mechanical weathering. The process of chemical weathering generally occurs in the soil where water and minerals are in constant contact.

Agents of weathering are oxygen, air pollution, water, carbonic acid, and strong acids. They combine with the minerals in rocks to form clays, iron oxides, and salts, which are the endpoints of chemical weathering.

WATER ABSORPTION TEST (IS: 2386-PART-3)

Water absorption of the five weathered rock sample collected from the various sites within the study area are tested. Water absorption of the weathered rock samples gives an idea of the capacity to hold water in the pores, joints and factures within the rock.

The samples having more water absorption are more porous in nature and can be stated as more prominent for water storage.

Table 3: Water Absorption of Weathered Rock Samples

Sr. No.	Location Area	Surface dry weight(W_3)(gm)	Oven dry weight(W_4)(gm)	Water absorption(%)
1	Manewada, East Nagpur	932.8	895.7	4.14
2	Upstream of lake, West Nagpur	1070.6	1121.4	4.81
3	Wardha Road, South Nagpur	1070.5	995.2	7.56
4	Ambazari lake, West Nagpur	997.2	902.2	10.53
5	Seminary Hills, North Nagpur	792.2	677.2	16.98

CONCLUSIONS

The overall conclusion from the generated five profiles is, the groundwater level in an unconfined aquifer follows the surface topography and varies along. The depth ranges according to the geological formations and the structures of the rock. Thus the topography of an area plays a vital role in the occurrence of the groundwater in an unconfined zone. It may also be concluded that the water absorption results indirectly predicts about the primary porosity in the rocks. The samples of Manewada area and Futala Lake show a lesser water absorption percent. The samples collected consist of Spheroidal core weathered samples which has the water absorption less. Spheroidal weathering occurs whenever a mass of rock, experiences a drastic reduction in ambient heat and pressure. Since it is a core material it has less water absorption rate. The extent of the weathering observed is highest at the Seminary hills. The unconfined aquifer system in Nagpur may be recharged significantly.

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