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Dynamics of the Groundwater Levels in Shallow Aquifers of WRC-1 Watershed, Chargarh River Basin, Central India

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Abstract

Shallow unconfined aquifer in hard rock terrain generally have complicated and heterogeneous hydrogeological setup. Present study incorporates dynamics of the static groundwater levels in the Chargarh river basin, Central India, during pre-monsoon and post-monsoon season, with special reference to lithological variation. The geological formations exposed in the basin are Deccan basalt and alluvium. The average pre-monsoon and post-monsoon static water levels in the basalt formation are 12.21 mbgl to 6.14 mbgl respectively, with 6.07-meter seasonal water table fluctuation. On the other hand, average pre-monsoon and post-monsoon static water levels (SWL) in the alluvial formation are 16.84 mbgl to 4.64 mbgl respectively, with 12.20 m the water table fluctuation (WTF). The pre-monsoon SWL in alluvium is deeper as compared to the pre-monsoon SWL in basalt. Similarly, WTF in alluvium is higher than WTF in basalt. These observations are reversed to that of the general assumption, that the WTF in soft rock formations are lower as compared to WTF in hard rock terrain. This can be attributed to the excessive withdrawal of groundwater for orange cultivation and sporadic artificial recharge structures in the alluvial formation.

Keywords: *Groundwater, Watershed, Lithology, Static water level, Water table fluctuation.*

1. Introduction

The most essential resource for human survival is groundwater, in addition to other eco-hydrological sources (Damilola and Olumide, 2015; Deshmukh and Taksande, 2021). The WRC- 1 watershed of Chargarh river basin is a part of Wardha river basin which is the part of the famous 'Orange belt' of Vidarbha region of Maharashtra (CGWB, 2017). Its area is famous for orange/sweet lime cultivation (CGWB, 2017). Over the period of years, the groundwater is being exploited for cultivation of oranges/sweet lime (CGWB, 2017). Due to which, groundwater development has been drastically raised (CGWB, 2017). On the contrary, the area shows a rise in water levels due to many reasons like assured rainfall in the region, construction of water conservation structures by various government agencies and non-government organizations, micro irrigation practices adopted by the farmers etc. (CGWB, 2017). The rate of aquifer recharge depends to a large extent on the infiltration capacity of the soil, percolation, evapotranspiration rate, subsurface lithology and the overland drainage characteristics of the area (Ngah et al., 2013).

Increasing demand of the groundwater needs to evaluate the existing trend and availability of groundwater in time and space for proper planning and sustainable development in the area (Rokade et al., 2019). Past decadal groundwater levels and rainfall details provide important facts and figures to analyses long term changes in groundwater system of an area (Rokade et al., 2019). The water level fluctuation between pre-monsoon and post-monsoon, depends on the local hydro-geological condition (Deshmukh, 2012). The groundwater level fluctuation is controlled by the recharge and draft of groundwater and the diverse influences on groundwater levels including meteorology, urbanization, earthquakes and external loads, stress and strain in water levels due to groundwater recharge, discharge and intensity of rainfall (Gopinath & Seralathan., 2008; Nandargi et al., 2014). The shape of annual water level fluctuation curve (annual cycle) of a piezometer is due to the specific characteristics of the aquifer and the way it responds to the recharge– discharge phenomenon (Mukherjee, et al., 2017). The level of water in a well or unconfined aquifer, while no water is being withdrawn from it by flow or pumping is known as the static water level (Ngah and Nwankwoala, 2013). It is commonly expressed as the distance between the ground and the water level in a well (Ngah and Nwankwoala, 2013). As the groundwater in the shallow aquifers is replenished annually, the status of water levels and their fluctuation are important factors in groundwater assessment (Maggirwar and Umrikar, 2011).

The hard rock aquifer saturation and extent of recharge are determined by the pre-monsoon and post-monsoon groundwater levels (Maggirwar and Umrikar, 2011). According to recent studies in India and Bangladesh, groundwater levels have been declining (0.1-0.5m/yr), indicating reduction in the aquifer storage for unsustainable groundwater abstraction, for both irrigation and rural and urban water supplies (Abdullahi and Garba, 2015). Continuous extraction of groundwater for increasing agricultural production in rural areas, coupled with groundwater development activities, has resulted in depletion of static water levels in many areas. Secondary porosity that develops over time as a result of weathering and decomposition processes gives hard rocks their status as an aquifer (Radhakrishna, 1971; Powar, 1981). Due to the shallow depth and secondary porosity of weathered mantle, groundwater is primarily found (Singhal, 1973, 1986). Groundwater is primarily sourced from vesicular, weathered, and fractured horizons in basalt. Hard rock aquifers are typically heterogeneous in nature and have limited potential. Generally, it is restricted to the weathered underlying material, fracture and fissure section up to a depth of 60 m (Maggirwar and Umrikar, 2011). Hard-rock aquifers are unconfined, and their water tables typically follow the topography of the surrounding terrain. As a result, the groundwater system and surface drainage (watershed) are well matched with aquifer geometry (Maggirwar and Umrikar, 2011; Deshmukh and Taksande, 2021). Aim of this study was to examine the variations in the static water levels with respect to lithological variations, in the pre-monsoon and post-monsoon seasons and also to analyse water table fluctuations in the unconfined aquifers of WRC-1 watershed, Chargarh river basin, Central India.

Study Area

The WRC- 1 watershed of Chargarh river basin is a part of Wardha river basin of Central India. It is covered by the Survey of India toposheets 55G/15, 55G/16, 55K/3 and 55K/4 and bounded by 77°45' to 78°05' E longitude and 21°0 to 21° 25 N latitudes, covering approximately 412.51 Sq.km area (Figure 1). The Chargarh river originates in Satpura mountain and flows due Northwest to Southeast.

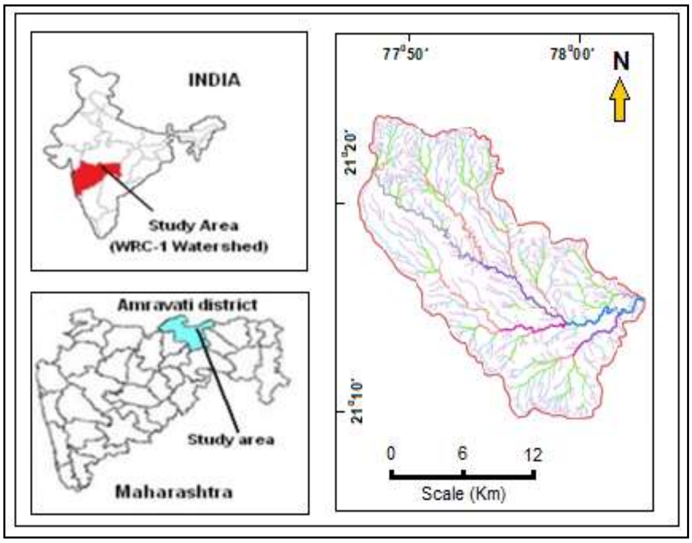

Figure 1: Location map of the study area.

2. Materials and Methods

The Survey of India toposheets 55G/15, 55G/16, 55K/3 and 55K/4 (1: 50,000 scale) are utilized as base maps. The comprehensive hydrogeological information was collected by examining 23 open dug wells (representing unconfined aquifers). A special well inventory sheet was utilized to collect hydrogeological information, during pre-monsoon and post-monsoon seasons. Altitude of the wells with respect to mean sea level were recorded with the help of GPS, to correlate the static groundwater levels with respect to mean sea level (to identify depth to water level). The measuring tape of 30-meter length was utilized to measure depth, diameter, static water levels in a well etc. The Geographical Information

System (GIS) software was utilized to process hydrogeological data and also to generate hydrogeological maps. The pre-monsoon and post-monsoon static water level maps and seasonal water table fluctuation maps where prepared using Are-Map 10.2 software.

Geological Setting

The Deccan basalt exposed in the central and northern parts of the watershed belongs to the Upper Cretaceous to Lower Eocene age, whereas Quaternary alluvium belongs to the Cenozoic age (DRM, GSI, 2001). The basaltic lava flows belong to Sahyadri Group of the Deccan Trap Formation, which is stratigraphically categorized as Chikhli, Karanja, and Ritpur Formations (GSI, DRM, 2001). The six non-porphyritic to moderately porphyritic lava flows are exposed in the area are designated as Chikhli Formation (GSI, DRM, 2001). The lava flows range in thickness from 45 meters to 130 meters. The Karanja Formation has 8 to 14 non-porphyritic to strongly porphyritic 'Aa' basalt lava flows. The Rithpur Formation consists of 7 'Aa' lava flows of non-porphyritic nature, with thickness ranges from 55 to 117 meters (DRM, GSI, 2001). Special field characteristics such as vesicular, amygdaloidal and compact massive nature of the basalt, as well as structural elements distinguish the individual basalt flow. Along with the basalt and alluvium, WRC-1 watershed is covered by the laterite, cherty limestone and boulder bed in small patches.

3. Result and Discussion

Dynamics of the Static Water Levels

The groundwater occurs under unconfined, semi-confined and confined conditions and flow downward from the weathered zone (saprolite and saprock) into the fracture zone. The main aquifer constitutes the weathered zone at the top, followed by a discrete anisotropic fractured/fissured zone at the bottom, generally extending down to 100 m depth (Madhnure, et al., 2015). The static groundwater reserve is the groundwater contained within the permanently saturated zone of groundwater reservoir and represents the total groundwater reserve minus dynamic reserve (Karanth, 1987). The aquifer is a layer of water (Van der Wal, 2010). Exploration of groundwater resources necessitates a thorough understanding of the geology of the study area, hydrogeology and geomorphology (Sonar, et al, 2018). It is critical to monitor and conserve groundwater resources so that the same can be accessed reliably in the future, avoiding any problems with its qualitative and quantitative availability (Varade, et al., 2011). One of the fundamental data elements that reflect the groundwater regime in any area is the groundwater level. The primary goal of ground water level monitoring is to record the response of the groundwater regime to natural and anthropogenic stresses on recharge and discharge components, which are governed by geology, climate, physiography, land use pattern and hydrologic characteristics (CGWB, 2019). The static groundwater levels and water level fluctuation also reflect the volume of water available during pre-monsoon and post-monsoon season, within the watershed (Deshmukh, et al., 2021).

The Central Ground Water Board (CGWB) has conducted systematic hydrogeological assessments of the Morshi and Chandur Bazar areas and frequently monitored water levels and water quality, using observation wells (GSDA and CGWB, 2014). The Central Groundwater Board and Groundwater Survey and Development Agency conducted a periodic river watershed wise groundwater evaluation, which covered recharge, draft and net available balance for future use. Accordingly, Morshi and Chandurbazar tahsil areas are declared as overexploited (CGWB and GSDA, 2005; CGWB and GSDA, 2014). According to Abiye, et al. 2018, successful management of groundwater resources depends on the available resource and degree of groundwater fluctuations.

A detailed examination of the spatio-temporal variation in static water levels reveals important information about the aquifer system (Deshmukh and Taksande, 2017). It is observed that water table fluctuation in the WRC-1 watershed ranges between 1 to 16 meters (Table 1) in different parts, which is controlled by lithological variations. The Chargarh river basin is predominantly covered by the Deccan basaltic lava flows where the successive lava flows (upper vesicular and lower jointed, fractured massive units) act as different aquifer systems. This aquifer has different water holding, transmitting and yield capacities. The study area is covered in a thick layer of black soil, which is followed by a vesicular and massive basalt portion of shallow unconfined aquifer, which is tapped by open dug wells. The range of static water level (SWL) during the pre-monsoon season (2021) varies from 2 to 29.7 mbgland the range of static water level (SWL) during post-monsoon season (2021) vary from 1 to 18.6

mbgl, with 1 to 16 m water level fluctuation which is observed in northern, North-eastern, North-western, South-eastern and Western part of the area covered by the Deccan basalt and Alluvium. The high groundwater level fluctuation between 9 to 16 meter is observed in the alluvial part (North-West and South-East part of the watershed), especially along the Wardha river course. The low groundwater level fluctuation i.e. between 0.1 to 3 mbgl is observed in the northern, North-eastern, South-eastern and South-western part of the area which may be due the insufficient depth of the wells in hard rocks. The moderate fluctuation between 3 to 9 meterbgl is observed towards South-western, South-eastern, Central, North-eastern and North-western part. The high groundwater level i.e., 9 to 16 mbgl is observed towards North-western and South-eastern part of the study area, specially along the wardha river course probably due to excessive withdrawal of groundwater for orange orchid cultivation. On the large scale, the Static water levels increase fairly from North to South direction and accordingly major regional direction of groundwater flow trends from South to North.

The average pre-monsoon and post-monsoon static water levels (SWL) in the basaltic terrain are 12.21 mbgl to 6.14 mbgl respectively, with 6.07-meter water table fluctuation (WTF) (Fig. 2, 3, 4). On the other hand, average pre-monsoon and post-monsoon static water levels (SWL) in the alluvium are 16.84 mbgl to 4.64 mbglrespectively with 12.20-meter water table fluctuation (WTF) (Table 2, Fig. 2, 3, 4, 5, 6). Analysis of the SWL in pre-monsoon and post-monsoon seasons and seasonal water table fluctuation indicates influence of lithology and heavy withdrawal of groundwater for irrigation. Thus, lithological variations and groundwater draft influence both the static water levels and water table fluctuations.

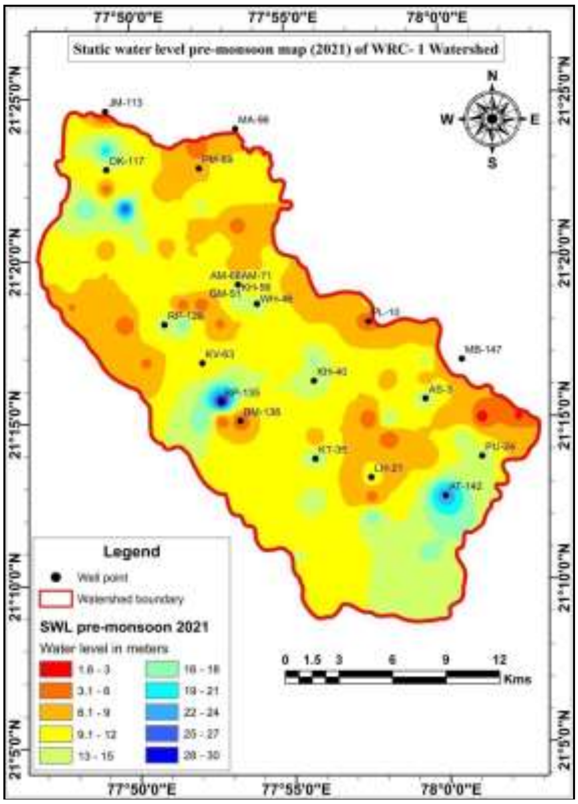

Figure 2: Pre-monsoon static water level in the WRC-1 watershed.

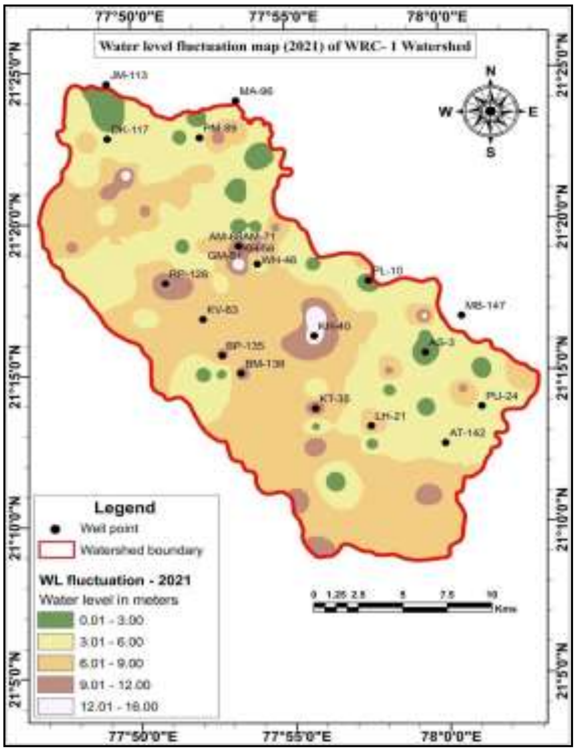

Figure 3: Water level fluctuations in the WRC-1 watershed.

Table 1: Static groundwater levels and water table fluctuations in the WRC-1 watershed.

Well ID	Locality	Tahsils (Of Amravati District)	Altitude	Depth of the wells (mbgl)	Pre-Monsoon SWL (mbgl)	Post monsoon SWL (mbgl)	Water table fluctuations (WTF in meter)	Lithology
AS-3	Asona/ Ladki	Morshi	348	13.7	10.7	3	7.7	WR+JMB+VB+LS
SH-8	Shirkhed (Mauza-Daryapur)	Morshi	343	18.6	13.5	8.9	4.6	WR+BCS+MB+VB
PL-10	Pimpulkhuta	Morshi	372	18.28	14.54	14.54	0	WR+MCB+VB+ CJ
LH-21	Lehegaon	Morshi	340	14.63	11.9	3.36	8.54	WB+CMB
PU-24	Pusala (Mauza Naya Vathoda)	Morshi	332	21.03	14.49	8.39	6.1	LS+VB+ CMB
KT-35	Katpur	Morshi	350	19.81	16.17	3.97	12.2	CMB
KH-40	Khopda	Morshi	350	24.25	13.3	10.95	2.35	WB+CMB
WH-46	Warha fata	Morshi	378	21.33	14.33	1.83	12.5	LS+WB+VB+MB
GM-51	Mauza-Gujarmali	Morshi	383	23.46	12.71	2.95	9.76	WB++SW+VB+ MB
KH-56	(Mauza-Gujarmali	Morshi	388.51	13.1	9.6	2.7	6.9	LM+SW+AB+MS
KV-63	Mauza-Kolvihir	Morshi	382	13.71	9.15	1.53	7.62	LS+ WR+AB+MB
AM-68	Ambada	Morshi	390	24.38	21.34	7.32	14.02	FJB+MB
AM-71	Mauza Ambada	Morshi	396	28.65	21.65	9.46	12.19	WB+MB
PM-89	Pimpri	Morshi	391.1	10.66	6.4	4.26	2.14	LS+WR+SW+MB
MA-96	Maniardi	Morshi	449	18.28	10.67	2.74	7.93	WR+SW+VB+MB
JM-113	Jamapati	Chandur bazar	485	7.62	2	1	1	JFMB
DK-117	Dhakla	Chandur bazar	463	10.7	10.9	3.7	7.2	LS+WB+CMB+MB
RP-128	Raipur (Taroda)	Morshi	384	18.28	14.2	1.5	12.7	LS+R+WB
BP-135	Bispur (vishnora)	Morshi	371	38.1	29.7	13.7	16	S+R+JB+ +LS

BM-136	Barhanpur	Morshi	364	12	3.5	1.1	2.4	WB+FB+VB+SW+MB
AT-142	Akatwada	Morshi	332	25	23.4	18.6	4.8	WB+CB+MB
MB-147	Mamdabad	Morshi	355	16.7	5.3	1.4	3.9	WB+CB+MB
KB-149	Kelbehra	Chandur bazar	482	12.19	10.1	8.4	1.7	SW+WB+CMB+AB

(WR: weathered rock, BCS: Black cotton soil, MB: Massive basalt, VB:Vesicularbasalt,AVB:Amygdaloidal/ Vesicular basalt, GB:Green bole, RB:Red bole, FSR:Fissured rock, CMB: Compact massive basalt, CJ: Columnar joint, JMB: Jointed massive basalt, LM:Limestone, LS:Loose soil/Unconsolidated rock, WB: Weathered basalt, SW:Spheroidal weathering, MB:Massive basalt, FJMB: Fractured and Jointed massive Basalt, JB- Jointed basalt, LT: Laterite, FB:Fractured basalt, AB:Amygdaloidal Basalt).

On the basis of static water level measurement in currently operational observation dug wells and corresponding altitude with respect to mean sea level, ground water level contour maps have been prepared (Figure 3 & 4). The groundwater level contour map of pre - monsoon period exhibits variations in nature of ground water levels. Widely spaced contours have been observed in SW-SE direction at Asona/Ladki, Shirkhed, Pimpalkhuta, Pusla, Lehgaon, Katpur, Akatwada, Mamdabad, Kelbehra etc. indicating groundwater potential sites in the study area and the closely spaced contour observed in NW-NE direction at Khopda, Warha Fata, Gujarmali, Kolvihir, Ambada, Pimpri, Mainardi, Jamapati, Dhakla, Raipur, Bispur and Barahanpur area indicates poor groundwater potential.

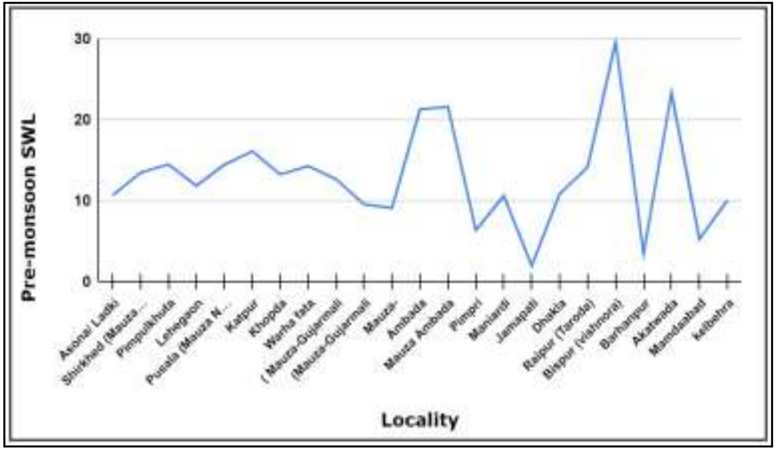

Figure 4: Pre-monsoon static groundwater levels of the WRC-1 watershed.

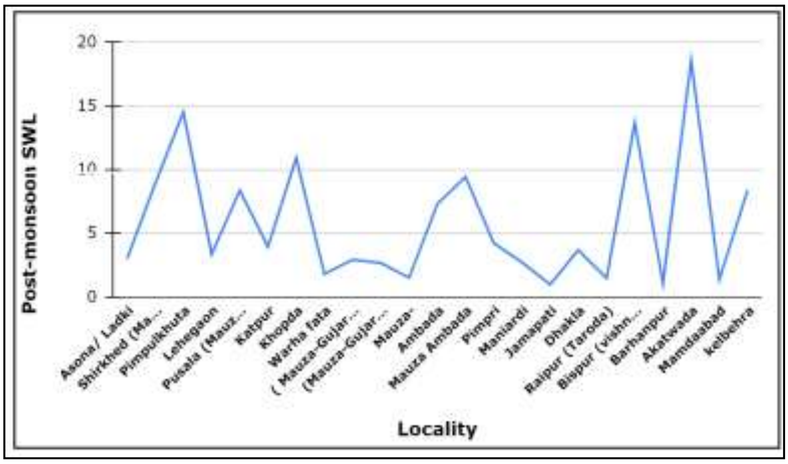

Figure 5: Post-monsoon static groundwater levels of the WRC-1 watershed.

Table 2: Average pre-monsoon and post-monsoon static groundwater levels and water table fluctuation in different geological formations.

Sr. No.	Formation	Average SWL (mbgl)		Average seasonal water level fluctuation (meter)
		Pre-monsoon	Post-monsoon	
1	Basalt	12.21	6.14	6.07
2	Alluvium	16.84	4.64	12.20

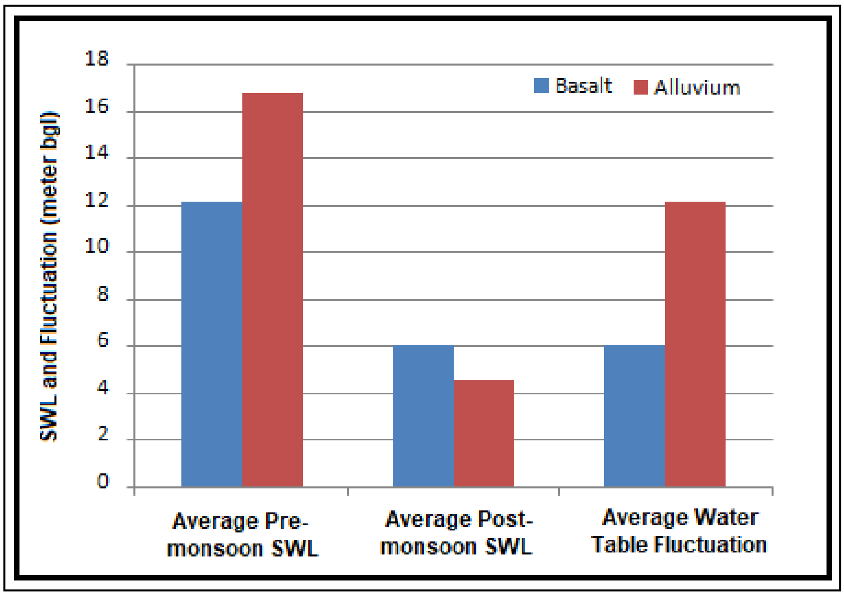

Figure 6: Average pre-monsoon and post-monsoon static groundwater levels and water table fluctuation in the basalt and alluvium.

4. Conclusion

Present investigation elucidates very complicated geological structure of the Chargarh watershed, which is reflected in the static groundwater levels. As the basin is covered by the Deccan basalt and alluvium, shallow, intermediate, and deeper groundwater levels are represented by the alluvium and Deccan basalt (in the vesicular, amygdaloidal, jointed and weathered zone). The pre-monsoon static water levels are shallow at Asona/Ladki, Jamapati, Burhanpur, Pimpri, Mainardi, Dhakla, Mamdabad, Kelbehra village area (Fig. 3). The pre-monsoon static water levels are deeper in Shirkhed, Pimpalkhuta, Lehgaon, Pusala, Mauza Naya Vathoda, Katpur, Khopda, Warha, Gujarmali, Kolvihir, Ambada, Raipur, Bispur, Akhatwada area (Fig. 3). The average pre-monsoon and post-monsoon static water levels in the basalt formation are 12.21 mbgl to 6.14 mbgl respectively, with 6.07-meter water table fluctuation. On the other hand, the average pre-monsoon and post-monsoon static water levels in the alluvial formation are 16.84 mbgl to 4.64 mbgl respectively, with 12.20-meter water table fluctuation. The pre-monsoon static water level in the alluvial formation is deeper as compared to the pre-monsoon static water level in the Deccan basalt of the area. Similarly, water table fluctuation in alluvium is greater than water table fluctuation in basalt. These observations are reversed to that of the general assumption, that WTF in soft rock formations are lower as compared to WTF in hard rocks. This can be attributed to the excessive withdrawal of groundwater for orange cultivation and sporadic artificial recharge structures in the alluvial formation.

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Author’s Contributions

Manish S. Deshmukh: Conceptualization, Supervision, Review.

Apurva D. Fuladi: Hydrogeological Investigation, Formal Analysis, Writing and Editing.

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