

# Spatio-Temporal Variation and Trend Analysis of Groundwater Level in Raipur City, Chhattisgarh

Sumant Kumar, Surjeet Singh, R. V. Kale, N. C. Ghosh, Mahesh M. Sonkusare and S. K. Chandniha

**Abstract** Assessment of spatio-temporal variation provides a principal source of information regarding groundwater recharge, storage and discharge. Spatio-temporal variation of groundwater level (GWL) in Raipur city has been studied using statistical and graphical methods. Monthly trend of GWL has been investigated using Mann–Kendall test and Sen’s slope estimator. The monthly GWL data of thirty observation wells (dug well) of Raipur city for the period 2010–2014 have been used for the study. The minimum and maximum GWL has been found out to be 0.84 m below ground level (bgl) which is 267.98 m above mean sea level (amsl) and 16.61 m bgl (271.53 m amsl). Contour map shows that average GWL varies between 1.74 and 13.80 m bgl (i.e. 280.34 m to 287.12 amsl) during pre-monsoon and 1.64 m to 6.75 m bgl (i.e. 279.92 m to 282.54 m amsl) during post-monsoon. GWL is shallower in central part of the city, whereas deeper GWL has been observed in western and northern part of the city. The groundwater contour maps depict that the groundwater flow direction is towards north and west. The results of trend analysis reveal that no significant trend is detected at 5% significance level except few locations.

**Keywords** Raipur · Groundwater level · Trend · Well · Mann–Kendall test

## Introduction

Groundwater is preferred source for drinking and irrigation purposes in rural as well as urban areas in India. Increasing population and their dependence on groundwater cause heavy stress on groundwater resources, leading to decline of groundwater levels (Chopra and Krishan 2014; MacDonald et al. 2013; Rodell et al. 2009). To

---

S. Kumar (✉) · S. Singh · R. V. Kale · N. C. Ghosh · S. K. Chandniha  
National Institute of Hydrology, Roorkee 247667, India  
e-mail: sumantk@nih.ernet.in

M. M. Sonkusare  
CGWB, NCCR, Raipur, India

prepare a sustainable management strategy for groundwater development, it is important to understand the fluctuation of groundwater levels (GWL) with reference to natural or artificial recharge and abstraction of groundwater in space and time domain. The spatial and temporal variations in the GWL were investigated by many researchers. Finke et al. (2004) and Ahmadi and Sedghamiz (2007) used kriging for mapping of groundwater level to identify critical area.

Geostatistical methods are good tools for water resource management and can be effectively used to derive the long-term trends of the groundwater (Raghnunath et al. 2005). Statistical methods for trend analysis vary from simple linear regression to more advanced parametric and nonparametric methods (Helsel and Hirsch 2002). Many researchers (Arora et al. 2005; Dash et al. 2007) investigated rainfall and temperature trend analysis, but few studies have been done for GWL trend analysis. Few researchers (Shamsudduha et al. 2009; Hossein and Shifteh 2011) attempted to study trend analysis using statistical methods for analysing groundwater levels. Hossein and Shifteh (2011) investigated the temporal trends in annual, seasonal and monthly groundwater levels using Mann–Kendall test and the Sen’s slope estimator. Shamsudduha et al. (2009) studied recent trends in groundwater levels in highly seasonal hydrological system of Ganges–Brahmaputra–Meghna Delta of Bangladesh using nonparametric techniques. In the present study, spatio-temporal variations of groundwater level in Raipur city, Chhattisgarh, have been analysed. The monthly trend analyses using Mann–Kendall (MK) and Sen’s slope test have also been ascertained. The study will provide useful input to the engineers and water resource planners for development and management of groundwater resources.

## Study Area

The study area (Fig. 1) comprised of Raipur city, the capital city of Chhattisgarh, along with its outgrowths lies between  $21^{\circ} 10'$  and  $21^{\circ} 21'N$  latitudes and  $81^{\circ} 32'$  to  $81^{\circ} 44'E$  longitudes and falls under Survey of India toposheets number 64G/11 and 64G/12. The present population of Raipur city is about 1,200,000. Water supply requirement of the city is mainly met from Kharun River—a tributary of Mahanadi River. Approximately 65% of the city’s drinking water supply is met from Kharun River, and the rest is supplied from groundwater resources developed through hand pumps and tube wells. In general, Raipur area features semi-arid tropical climate having hot long summer from March to mid-June followed by rainy season of about four months from mid-June to September. The winter season commences from December and continues till end of February. The annual rainfall varies from 831 to 1719 mm with average rainfall of 1207 mm (Saph 2013).

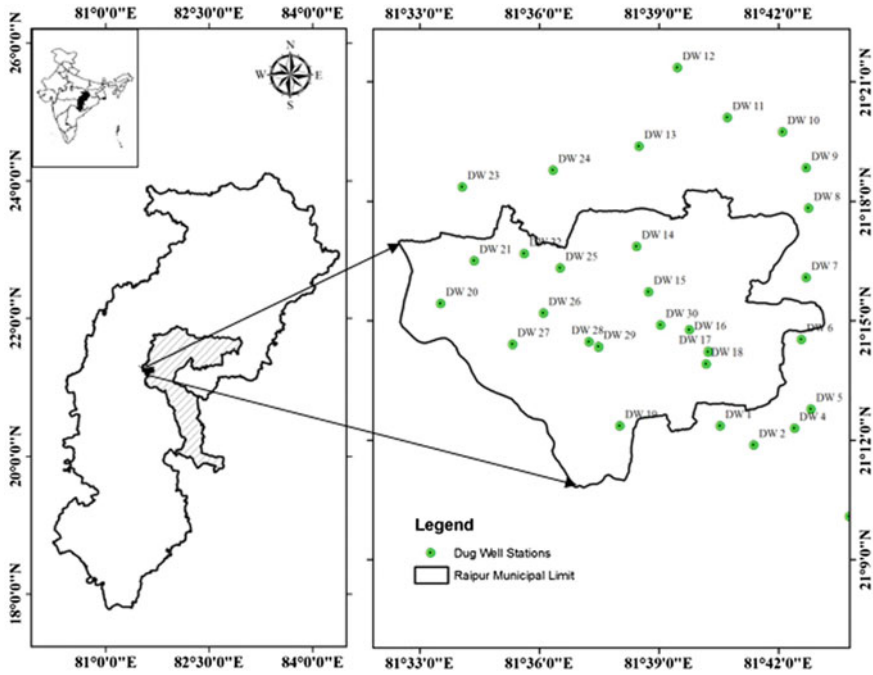


Fig. 1 Study area (Raipur city) with observation wells in and around the city

## Data and Methodology

Monthly GWL of 30 observation wells (dug well) during the period of five years (2010–2014) of Raipur urban area collected from CGWB, Raipur, has been used for the analyses. Spatial and temporal variations have been analysed for observation wells to predict groundwater flow direction and fluctuations in the respective wells. The groundwater levels are available at the depth below ground surface; therefore, by collecting the RL of the respective well locations, these data were converted to groundwater level above msl and then georeferenced with respect to their latitude and longitude. Trend analysis, using MK test and Sen’s slope, has been performed for each wells based on monthly data. The MK test is one of the most commonly used nonparametric method, most of the literature significantly contains this approach for trend analysis. Magnitude of trend has been quantified by Theil–Sen’s estimator, and positive and negative values of magnitude showed increasing and decreasing trend, respectively. The minimum and maximum GWL observed in dug wells during five years period has been presented in Table 1. Dug wells are shallow-depth wells, and groundwater levels indicate the level of phreatic aquifer.

**Table 1** Dug well identification and coordinates with minimum and maximum GWL

Dug well ID	Location name	Latitude	Longitude	Minimum GWL m bgl	Maximum GWL m bgl
DW 1	Deopuri	21.206	81.676	1.61	14.20
DW 2	Dumartarai	21.198	81.690	1.02	9.97
DW 3	Mana Basti	21.168	81.730	1.47	10.74
DW 4	Temri	21.205	81.707	0.95	5.32
DW 5	Dharampura	21.213	81.714	0.91	6.70
DW 6	Jora	21.242	81.710	0.95	7.66
DW 7	Kachna	21.268	81.712	1.07	8.70
DW 8	Baronda	21.297	81.713	0.97	7.00
DW 9	Bhurkoni	21.314	81.712	1.04	8.50
DW 10	Tekari	21.329	81.702	0.86	7.80
DW 11	Giroud	21.335	81.679	0.98	6.60
DW 12	Sankra	21.356	81.658	1.10	12.86
DW 13	Rawabhata	21.323	81.642	0.87	6.17
DW 14	MVH Colony	21.281	81.641	0.97	3.77
DW 15	Shastri Nagar	21.262	81.646	0.93	7.30
DW 16	Shankar Nagar	21.246	81.663	1.31	2.67
DW 17	Telibandha	21.237	81.671	1.13	3.65
DW 18	New Purena	21.232	81.670	0.98	8.87
DW 19	Math Purena	21.206	81.634	1.31	3.15
DW 20	Tatibandh	21.257	81.559	1.80	16.61
DW 21	Jarwai	21.275	81.573	0.91	12.28
DW 22	Sondongri	21.278	81.594	1.12	4.37
DW 23	Guma	21.306	81.568	0.95	8.67
DW 24	Urla	21.313	81.606	1.28	13.37
DW 25	Gogaon	21.272	81.609	1.26	10.92
DW 26	Kota	21.253	81.602	0.84	7.25
DW 27	RSU	21.240	81.589	2.32	9.12
DW 28	Ashram	21.241	81.621	1.24	5.66
DW 29	Amapara	21.239	81.625	1.52	4.62
DW 30	Raja Talab	21.248	81.651	0.98	5.70

## Results and Discussion

The minimum depth to water (0.84 m bgl) has been observed in July 2010 at Kota, whereas maximum value (16.61 m bgl) observed in May 2012 at Tatibandh, based on five years GWL monthly data. The pre- and post-monsoon groundwater contours maps (Fig. 2a, b) depict the spatial variation of average groundwater level. The average groundwater level in pre-monsoon (month—May) varies from 1.74 to 13.80 m bgl (i.e. 279.92 m to 282.54 m amsl), whereas during post-monsoon

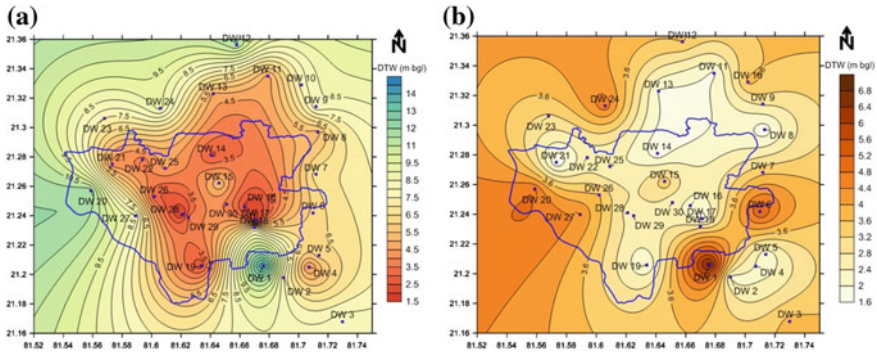


Fig. 2 DTW contour map for a pre-monsoon b post-monsoon

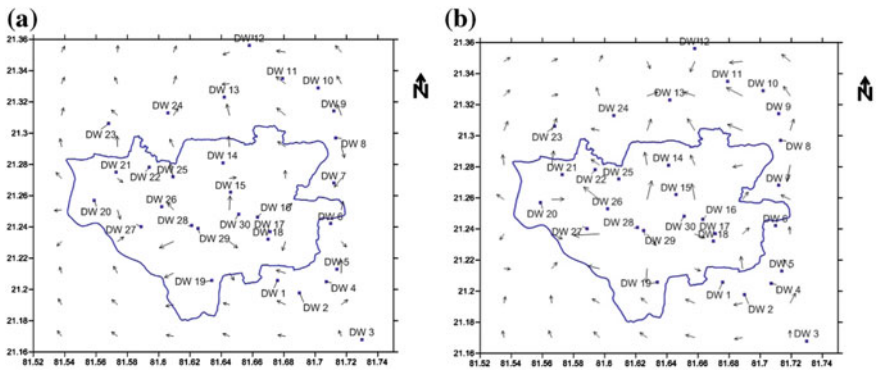


Fig. 3 GW flow direction during a pre-monsoon b post-monsoon

(month-November) groundwater level varies from 1.05 to 6.75 m bgl. GWL is shallower in central part of the city, whereas deeper GWL can be observed in western and northern part of the city. Groundwater flow direction in the area helps us decide the location of abstraction wells and pollutant transport path. The directions of the groundwater flow are found similar for the pre- and post-monsoon periods (Fig. 3). The direction of groundwater flow is towards north and west.

Trend analysis was performed using Mann–Kendall test (at 5% significant level) and Sen’s slope estimator method for monthly groundwater level. The summarised results of trend analysis have been presented in Table 2. The negative *S*-statistics indicate a falling trend and vice versa. The computed *Z*-statistics less than the *z*-value corresponding to 5% significance level (1.96) indicate no significant trend. It can be observed from Table 2 that groundwater level is showing falling and rising trend, which are not significant except few locations. There are few locations viz. Telibandha, Shankar Nagar, Gogaon, where groundwater level shows significant rising trend, whereas Math Purena showing significant falling trend.

**Table 2** Summarised results of trend analyses for each observation wells

Station	DW 1	DW 2	DW 3	DW 4	DW 5	DW 6
Location	Deopuri	Dumartarai	Mana Basti	Temri	Dharampura	Jora
S-statistics	-140	-234	-133	-19	-139	58
Z-statistics	-1.164	-1.949	-1.104	-0.151	-1.155	0.477
Trend	Falling	Falling	Falling	Falling	Falling	Rising
Significant (5%)	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant
Sen slope	-0.044	-0.041	-0.024	-0.002	-0.019	0.004
Intercept	-6.373	-1.894	-3.641	-2.387	-2.263	-5.872
Station	DW 7	DW 8	DW 9	DW 10	DW 11	DW 12
Location	Kachna	Baronda	Bhurkoni	Tekari	Giroud	Sankra
S-statistics	-95	-207	-150	0	-124	-216
Z-statistics	-0.786	-1.723	-1.247	-0.008	-1.029	-1.799
Trend	Falling	Falling	Falling	No Trend	Falling	Falling
Significant (5%)	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant
Sen slope	-0.015	-0.022	-0.022	0	-0.011	-0.042
Intercept	-4.211	-1.744	-3.918	-4.58	-1.967	-3.482
Station	DW 13	DW 14	DW 15	DW 16	DW 17	DW 18
Location	Rawabhata	MVH Colony	Shastri Nagar	Shankar Nagar	Telibandha	New Purena
S-statistics	38	-101	18	371	548	-171
Z-statistics	0.31	-0.837	0.142	3.098	4.577	-1.422
Trend	Rising	Falling	Rising	<b>Rising</b>	<b>Rising</b>	Falling
Significant (5%)	Not significant	Not significant	Not significant	<b>Significant</b>	<b>Significant</b>	Not significant
Sen slope	0.004	-0.006	0.001	0.007	0.011	-0.027
Intercept	-2.325	-1.915	-2.339	-2.382	-1.868	-3.952
Station	DW 19	DW 20	DW 21	DW 22	DW 23	DW 24
Location	Math Purena	Tatibandh	Jarwai	Sondongri	Guma	Urla
S-statistics	-319	206	198	113	105	55
Z-statistics	-2.661	1.715	1.648	0.937	0.87	0.452
Trend	<b>Falling</b>	Rising	Rising	Rising	Rising	Rising
Significant (5%)	<b>Significant</b>	Not significant	Not significant	Not significant	Not significant	Not significant
Sen slope	-0.008	0.043	0.01	0.009	0.018	0.013
Intercept	-1.913	-7.509	-2.236	-3.265	-4.734	-4.627
Station	DW 25	DW 26	DW 27	DW 28	DW 29	DW 30
Location	Gogaon	Kota	RSU	Ashram	Amapara	Raja Talab
S-statistics	247	50	-168	-102	16	179

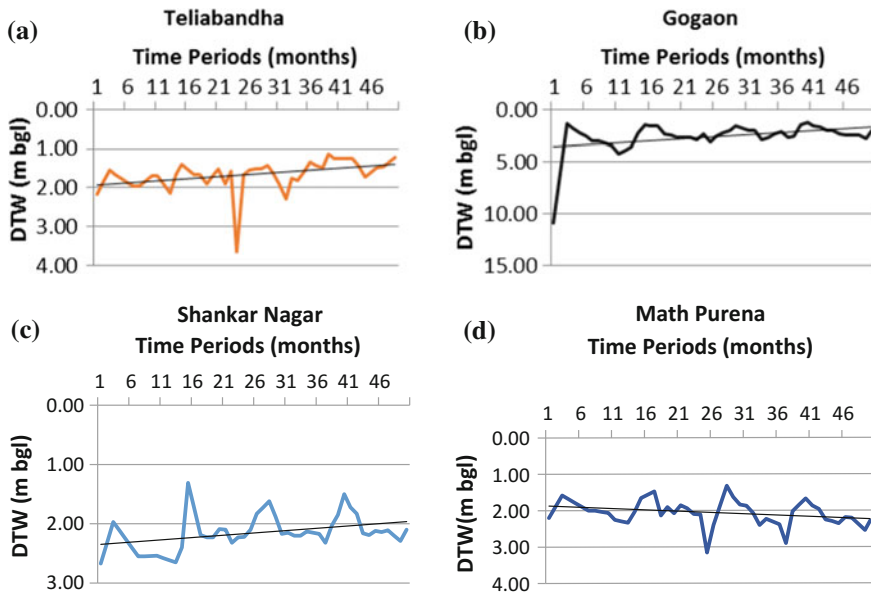
(continued)

**Table 2** (continued)

Station	DW 19	DW 20	DW 21	DW 22	DW 23	DW 24
Z-statistics	2.058	0.41	-1.397	-0.846	0.126	1.489
Trend	<b>Rising</b>	Rising	Falling	Falling	Rising	Rising
Significant	<b>Significant</b>	Not significant	Not significant	Not significant	Not significant	Not significant
Sen slope	0.016	0.003	-0.032	-0.002	0	0.01
Intercept	-2.882	-2.345	-5.224	-1.592	-3.062	-2.61

Magnitudes of above trends are calculated using Sen’s slope estimator method and have been presented in Table 2. A positive slope gives rising trend and vice versa. It is noticed that the trend pattern is same as detected using Mann–Kendall analysis.

The time series plot of GWL with linear trend for the locations showing significant rising or falling trend has been shown in Fig. 4. The rising trend of some wells maybe due to recharge from water bodies and less or no abstraction of groundwater from phreatic aquifer.



**Fig. 4** Time series plot for depth to water for **a** Teliabandha area showing rising trend **b** Gogaon area showing rising trend **c** Shankar Nagar showing rising trend **d** Math Purena showing falling trend

## Conclusions

The present study has been carried out to study the spatio-temporal variation and trend analysis of groundwater level in the Raipur city, Chhattisgarh. For the study, monthly groundwater level of 30 observation wells (dug well) for the period of five years (2010–2014) have been used. The minimum depth to water (0.84 m bgl) has been observed in July 2010 at Kota, whereas maximum value (16.61 m bgl) observed in May 2012 at Tatibandh. The average groundwater level in pre-monsoon varies from 1.74 to 13.80 m bgl, whereas during post-monsoon it varies from 1.05 to 6.75 m bgl. The shallower GWL has been observed in central part of the city. The direction of groundwater flow is towards north and west. The trend analysis is carried out using the Mann–Kendall analysis and Sen’s slope estimator method. It may be concluded that no significant trend is detected at 5% significance level except four locations. Locations showing significant rising trend are Telibandha, Shankar Nagar, Gogaon, whereas Math Purena shows significant falling trend.

**Acknowledgements** Authors are thankful to Director, National Institute of Hydrology, Roorkee, for granting necessary administrative and financial support to carry out this work.

## References

- Ahmadi SH, Sedghamiz A (2007) Geo statistical analysis of spatial and temporal variations of groundwater level. *Environ Monit Assess* 129:277–294
- Arora M, Goel NK, Singh P (2005) Evaluation of temperature trends over India. *Hydrol Sci J* 50 (1):81–93
- Chopra RPS, Krishan Gopal (2014) Assessment of groundwater quality in Punjab. *J Earth Sci Clim Chang* 5(10):243. doi:[10.4172/2157-7617.1000243](https://doi.org/10.4172/2157-7617.1000243)
- Dash SK, Jenamani RK, Kalsi SR, Panda SK (2007) Some evidence of climate change in twentieth-century India. *Clim Chang* 85:299–321
- Finke PAD, Brus J, Bierkens MFP, Hoogland TKM, de Vries F (2004) Mapping groundwater dynamics using multiple sources of exhaustive high resolution data. *Geoderma* 123:23–39
- Helsel DR, Hirsch RM (2002) Statistical methods in water resources. Book 4, hydrologic analysis and interpretation, US Geological Survey, Virginia, 510
- Hossein T, Jaefar N, Shifteh SB (2011) Investigation of groundwater level fluctuation in north of Iran. *Environ Earth Sci* 66:231–243
- Macdonald A, Bonsor H, Rao S, Someshwar M, Gopal K, Frank Van S, Ahmed K, Shamsudduha M, Dixit A, Moench M (2013) Groundwater topologies in the Indo Gangetic basin. In: Proceedings of international conference on advances in water resources development & management held at PU, Chandigarh during 23–27 Oct 2013, p 2
- Reghunath R, Sreedhara Murthy TR, Raghavan BR (2005) Time series analysis to monitor and assess water resource: a moving average approach. *Environ Monit Assess* 109:65–72
- Rodell M, Velicogna I, Famiglietti JS (2009) Satellite-based estimates of groundwater depletion in India. *Nature* 460(7258):999–1002



- Saph P (2013) Documentation of acquired data and conceptual model of MAR impact as input for WP5 modelling (deliverable 2.2). Project supported by the European Commission within the Seventh Framework Programme Grant agreement No. 282911
- Shamsudduha M, Chandler RE, Taylor RG, Ahmad KM (2009) Recent trends in groundwater levels in a highly seasonal hydrological system: the Ganges Brahmaputra-Meghna Delta. *Hydrol Earth Syst Sci* 13:2373–2385