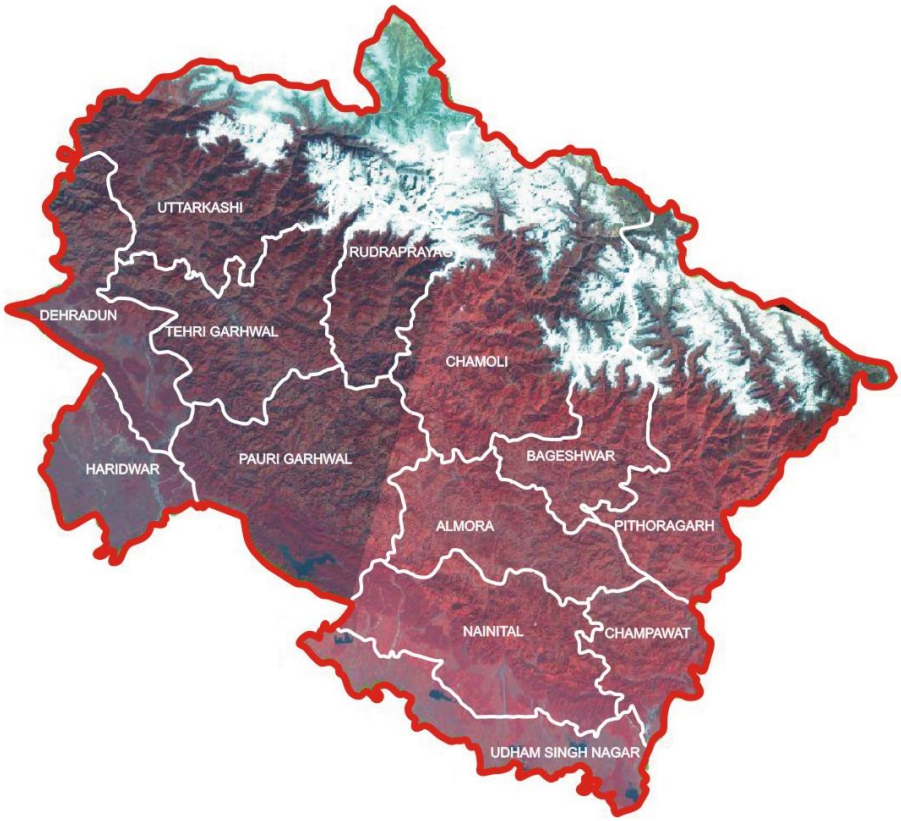
GROUND WATER YEAR BOOK 2016–2017

UTTARAKHAND

केन्द्रीय भूमि जल बोर्ड

Central Ground Water Board



उत्तरांचल क्षेत्र
Uttaranchal Region

मार्च 2018
March 2018

देहरादून
Dehra Dun

केन्द्रीय भूमि जल बोर्ड

Central Ground Water Board

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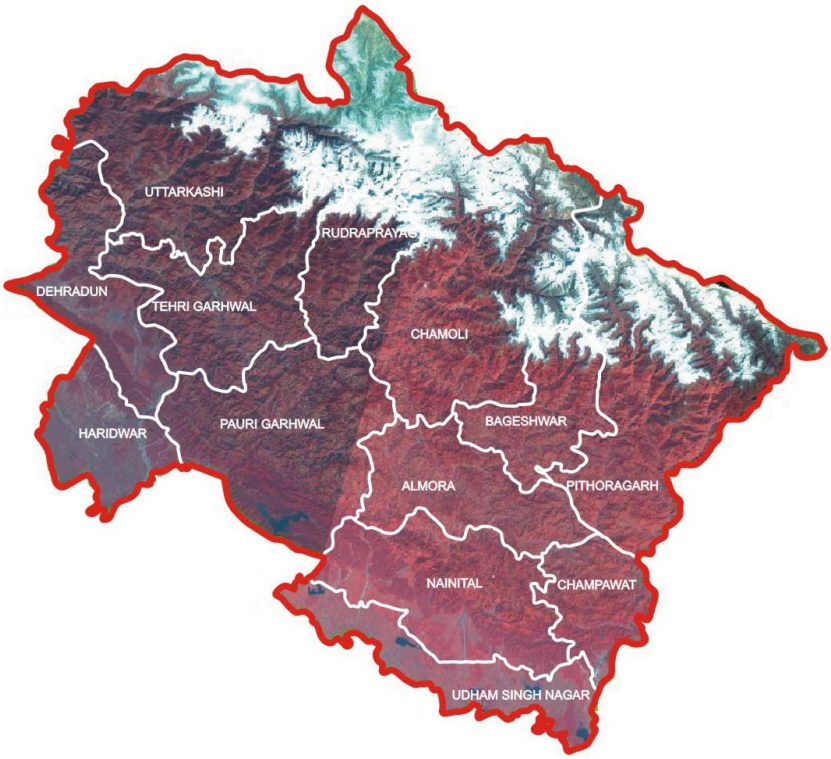
UTTARAKHAND

Contributor

Ms. Amandeep Kaur, Scientist –'B' (Jr. Hydrogeologist)



CENTRAL GROUND WATER BOARD

UTTARANCHAL REGION

DEHRA DUN

March 2018

FOREWORD

*WATER is one of the essential natural resources for sustaining life on blue planet "**Earth**". The demand of fresh / usable water has increased manifold globally due to rapid growth in population, which in turn caused change in agricultural pattern and increase in industrial activities. To meet the demand of fresh water of various sectors, there is an enormous stress on ground water resources as the surface water pollution is increasing day by day. This has resulted in the water level decline in many parts of the country as the output has outstripped input of this resource.*

*Ground water being a limited resource requires proper management and judicious use of its storage for meeting out demand on long term basis without putting any adverse impact on its regime. To meet this objective, Central Ground Water Board monitors the behaviour of ground water regime through a network of Ground Water Monitoring Wells spread across the country. The data collected from such wells in each state are compiled, processed and the salient features brought out as a "**Ground Water Year Book**". The present report pertains to the State of Uttarakhand for the year 2016 – 2017.*

Central Ground Water Board, Uttaranchal Region is monitoring the groundwater regime under various hydrogeological setting through 207 ground water monitoring wells in plain and hilly areas of Uttarakhand State, viz. Dehradun, Haridwar, Nainital, Udham Singh Nagar, Champawat, Almora, Pauri Garhwal and Uttarkashi districts four times in a year (January, May, August and November). In the hilly areas of the State Thirty-seven springs are also being monitored.

The district wise details of ground water levels are presented along with thematic maps depicting the fluctuations for specific period of measurement as well as for the decade. The data has been stored in appropriate format in the data storage center of the Regional Office, Dehradun.

The present Ground Water Year Book, 2016 – 2017 is the outcome of the effort made by Ms. Amandeep Kaur, Scientist- 'B' (Junior Hydrogeologist). The maps of the year book are prepared manually and then digitised. The efforts in depicting the groundwater scenario of Uttarakhand State through maps and giving proper shape to this report, is highly appreciable. The information and data presented in this report will serve as a database to the user agencies, ground water planners and managers and will be of immense use to understand the regional picture on the quantitative and qualitative aspects of ground water development in the State of Uttarakhand.

(Anurag Khanna)
Head of the Office

Place: Dehradun

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Executive Summary

The predominantly hilly Uttarakhand State was carved out of Uttar Pradesh in November 2000. The State comprises thirteen districts - Almora, Bageshwar, Chamoli, Champawat, Dehradun, Haridwar, Nainital, Pauri Garhwal, Pithoragarh, Tehri Garhwal, Rudraprayag, Udham Singh Nagar and Uttarkashi. The state is situated between latitude 28°43'20"N to 31°28'00"N and longitude 77°34'06"E to 81°01'31"E with a total geographical area of 53,483 km^2.

Uttarakhand State is broadly subdivided into two hydrogeomorphic units namely

1) Gangetic Alluvial Plain
2) Himalayan Mountain Belt.

Majority of area in the state falls under hilly terrain, except for Udham Singh Nagar, Haridwar and parts of Dehradun districts. Northern parts of the state remain under snow cover throughout the year. The drainage of the state is controlled by major rivers like Ganga (Gangotri) and Yamuna (Yamnotri), originating from the glaciers in high Himalayan Mountain Range and their tributaries like Ramganga, Kali, Saryu, Pindar etc. A variety of rock units ranging in age from Archean to Quaternary are exposed over the state. The rock units in the Himalayan mountain regions have undergone repeated phases of deformation and metamorphism after their formation.

In the plain areas, ground water occurs in multi aquifer systems. Perched water bodies lying above the main water bearing formations are frequently encountered in Bhabar Zone and Doon Valley. Contrary to this, the occurrence of ground water in the hilly areas is limited to small, localized aquifers with limited ground water potential. Ground water in hilly terrains is found in the secondary porosity developed in crystalline igneous and metamorphic rocks in the form of fractures, joints and fissures. Low to moderate ground water potential exists in parts of the state where ground water is located in valley fill deposits of the alluvial plains and piedmont zones. The chemical quality of ground water is generally good and the water can be safely used for drinking, domestic and irrigation purpose.

During the period May 2016 to January 2017, ground water monitoring in the state was carried out in parts of Dehradun, Haridwar, Udham Singh Nagar, Nainital, Champawat, Pauri Garhwal, Almora and Uttarkashi districts. A number of dug wells, hand pumps and few piezometers, which are the part of Ground Water Monitoring Wells of Central Ground Water Board, were monitored in the plain areas of these districts during the months of May, August and November 2016 and January 2017.

The depth to water level maps and water level fluctuation maps viz. decadal, annual and seasonal water level fluctuations were generated manually and then digitised by using coral draw software. These maps were prepared section wise viz. Dehradun Section, Haridwar section and Udham Singh Nagar-Nainital-Champawat section.

To assess the behaviour of ground water storage in space and time, the fluctuation in storage for each measurement has been evaluated with respect to decadal average value. A summary of depth to water level data in the State during the period May 2016 to January 2017 and the overall fluctuation pattern of ground water level (rise or decline) during the same period as compared to the long-term data (decadal average) are shown in tabular forms below. Moreover, annual fluctuation of water level (for the corresponding periods of May, August, November and January) and the fluctuation pattern of ground water level during the periods August 2016, November 2016 (post monsoon) and January 2017 as compared to May 2016 (pre monsoon) are also given in separate tables.

The status of water level fluctuation during each season/period with respect to observed data of pre-monsoon water level (May) during the same year indicated that decline in water level in the categories 0-2 m, 2-4 m and >4 m were significantly higher than the corresponding rise in the range of water level. The same situation was also observed for the annual water level fluctuation data also.

Summary of Depth to Water Data in Uttarakhand during the Period 2016 – 2017

State	**Range of depth to water level (m bgl)**	**Percentage of Wells Analyzed**			
		May 2016	**August 2016**	**November 2016**	**January 2017**
Uttarakhand	0–5	29.03	35.71	33.57	33.97
	5-10	25.16	27.27	25.71	21.15
	10-15	16.77	11.04	12.86	18.59
	>15	29.03	25.97	27.14	26.28

Fluctuation of Water Level during the Period 2016 – 2017 (Compared to Decadal Average)

State	**Fluctuation (m)**	**Percentage of Wells Analyzed**							
		Avg. May		Avg. August		Avg. November		Avg. January	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0–2	32.1	33.3	**23.3**	**42.5**	29.58	36.62	30.67	40.00
	2–4	7.69	10.3	**2.74**	**12.3**	4.23	8.45	8.00	6.67
	>4	6.41	7.69	**6.85**	**12.3**	5.63	15.49	1.33	13.33

Annual Fluctuation of Water Level during the Period 2016 – 2017

State	Fluctuation (m)	Percentage of wells analyzed							
		May 2015 vs. 2016		August 2015 vs. 2016		November 2015 vs. 2016		January 2016 vs. 2017	
		Rise	Decline	Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0–2	33.33	29.49	31.51	42.47	34.92	28.57	49.33	32.00
	2–4	10.26	3.85	2.74	2.74	9.52	12.70	6.67	2.67
	>4	17.95	5.13	13.70	6.85	7.94	6.35	5.33	4.00

Seasonal Fluctuation of Water Level (Compared to May 2016)

State	Fluctuation (m)	Percentage of wells analyzed					
		August 2016		November 2016		January 2017	
		Rise	Decline	Rise	Decline	Rise	Decline
Uttarakhand	0–2	38.16	10.53	41.32	11.57	47.44	12.82
	2–4	22.37	3.95	16.53	8.26	19.23	5.13
	>4	21.05	3.95	13.22	9.09	7.69	7.69

A perusal of various maps viz. depth to water level maps and water level fluctuation maps reveals that in general, many areas of Doon Valley (Dehradun district), parts of Haridwar district and Tarai Zone in Udham Singh Nagar district have shown both rise and decline in water levels of various magnitudes in different temporal aspects. Fluctuation in water level is more conspicuous in the Bhabar Zone in Nainital and Champawat districts than in the relatively plain areas of Central Ganga Plains in Haridwar district and in the Tarai zone in Udham Singh Nagar district. This Bhabar zone shows high ground water level fluctuation due to steep hydraulic gradient.

Chemical analysis of one hundred and seventy two (172) ground water samples collected from Ground Water Monitoring Wells from parts of Dehradun, Haridwar, Pauri Garhwal, Udham Singh Nagar, Nainital, Champawat and Almora district were analysed at the Chemical Laboratory, Central Ground Water Board, North Region, Luckhnow. The water samples were analyzed for fourteen parameters viz. Electrical Conductivity (EC), pH, carbonate, bicarbonate, chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium, potassium, silica and Total Hardness (TH) as $CaCO_3$.

The analysis of physico chemical parameters like Electrical Conductivity, chloride, nitrate and fluoride was done on the basis of data for pre-monsoon 2016. The analysis result indicates that high Electrical Conductivity (>750–2250 µS/cm) is observed in 8% of samples whereas majority of samples (74% of total) recorded EC value in the range of >250-750

µS/cm. The high EC may be either due to higher mineralization of ground water (geogenic) or due to industrial activity (anthropogenic). Data on chloride concentration in ground water samples indicates that relatively high chloride in the range of >100-150 mg/L is observed in only two samples, which was a bare minimum of 1% of the total number of samples.

High nitrate viz. higher than the acceptable Limit (>45 mg/L, BIS, 2009) is recorded in only one sample out of 142 samples. The 30 no of samples have shown nil concentration of nitrate in ground water during pre-monsoon, 2012. The high nitrate concentration recorded is 110 mg/L at Dharnauli in Almora district and 49 mg/L in a hand pump at Sultanpur in Haridwar district. High nitrate in ground water is attributed to anthropogenic source like unhygienic practices near the monitoring wells by the local populace. It is suggested the dug wells and hand pump in which high nitrate was observed should be avoided for drinking purpose and treated pipe line water should be used instead.

Chemical data on fluoride concentration in groundwater sample indicates that majority of samples (98% of total) has recorded fluoride less than the acceptable limit of 1.0 mg/L (BIS, 2009). High fluoride in the range of 1.0-1.5 mg/L and higher than the permissible limit (>1.5 mg/L) is also observed in single samples at Jaspur in Udham singh Nagar district and Dhalangaon in Almora district, respectively. High fluoride in ground water is attributed to geogenic source like leaching of fluoride from rocks and/or minerals into the groundwater system during rock-water interaction. It was found that fluoride concentration in groundwater is less in Dehradun-Haridwar section and relatively high in Udham Singh Nagar-Nainital section during pre-monsoon, 2016.

To conclude, the available hydrochemical data in parts of District Dehradun, Haridwar, Udham Singh Nagar, Pauri Garhwal, Nainital, Champawat and Almora (pre-monsoon 2016) in Uttarakhand State reveals that ground water is fresh and potable and therefore, suitable for drinking and domestic purpose.

CHAPTER – 1
INTRODUCTION

Ground water is a very important component of Earth's natural fresh water resource. Hence, ground water regime monitoring on periodic basis becomes essential for a safe and sustainable development and management of ground water resources of the hilly state of Uttarakhand. The directly measurable and often visible physical parameter of the otherwise invisible ground water system is the ground water level. Regular and systematic monitoring of ground water levels and evaluation of chemical parameters of ground water forms the base for scientific planning, development and management programmes. Scientific information about the behaviour of water level in time and in space becomes an essential exercise in this perspective. Indiscriminate withdrawal of ground water in rapidly developing urban and industrial areas poses a challenge to the scientific community. The challenge can be overcome by adopting sustainable ground water development and management practices.

Uttarakhand State lies between 28°43'20" – 31°28'00" N Latitude and 77°34'06" – 81°01'31" E Longitude and has a total geographical area of 53,483 km^2. The state has been divided into two Divisions and thirteen developmental blocks. Uttarakhand has a diverse hydrogeological set up. In order to assess the impact of continuously increasing stress on the ground water regime and to categorize various hydrogeological units in the State, systematic monitoring of ground water levels and spring discharge are being carried out four times in a year by the Central Ground Water Board, Uttaranchal Region, Dehradun through the Ground Water Monitoring Stations, which included periodic measurement of Springs discharge in the hilly terrain.

As on January 2017, a total of two hundred and seven ground water monitoring stations exist in Uttarakhand State, which are being monitored by the regional office four times in a year. The map showing locations of Ground Water Monitoring Wells and Springs in Dehradun, Haridwar, Nainital, Udham Singh Nagar, Champawat, Almora and Pauri Garhwal districts is shown as ***Fig. 1.***

Chemical analysis of water samples, collected from selected locations within the state once in a year during the month of May (pre-monsoon monitoring), is being carried out to check whether any significant change is taking place in groundwater quality in time and space.

The main objectives of ground water regime monitoring in Uttarakhand may be summarised as follows:

1. To study the fluctuation of water level, both spatially and temporally, in response to ground water recharge and/or discharge.
2. To evaluate changes in ground water level with respect to the preceding year for the same period.
3. To evaluate changes in ground water level with respect to a long term average water level such as the decadal mean.
4. To study the fluctuation of water level during different seasons of the period 2016 – 2017.
5. To study the hydrochemical behaviour of shallow aquifers.

The district wise break up of Ground Water Monitoring Stations (including the springs in hilly terrain), which were monitored during the period from May 2016 to January 2017 is given in ***Table 1.***

Table 1: District wise break up of active Ground Water Monitoring Stations (including Springs) monitored in Uttarakhand State

Sl. No.	*District*	*Number of Ground Water Monitoring Stations*			
		May 2016	*Aug 2016*	*Nov 2016*	*Jan 2017*
1.	Dehradun	55	53	51	54
2.	Haridwar	41	39	38	39
3.	Udham Singh Nagar	45	45	37	45
4.	Nainital	11	13	11	13
5.	Champawat	2	3	2	4
6.	Pauri Garhwal	1	1	1	1
7.	Almora	21	22	21	21
8.	Uttarkashi	12	12	10	11
TOTAL		**188**	**188**	**171**	**188**

Apart from the dug wells, hand pumps and piezometers, a total of thirty Seven springs in hilly areas of Uttarakhand were also monitored (as on January 2017). The details of these springs during the period May 2016 to January 2017 are given in ***Table 2.***

Table 2: District wise break up of Springs in Uttarakhand State

Sl. No.	*District*	*Number of Springs*			
		May 2016	*Aug 2016*	*Nov 2016*	*Jan 2017*
1.	Dehradun	3	3	3	2
2.	Nainital	6	7	7	7
3.	Almora	21	22	21	21
4.	Uttarkashi	6	7	7	7
TOTAL		**36**	**39**	**38**	**37**

The Ground Water Monitoring Stations (including Springs) have been further categorized on the basis of geological set up and catchments of the river basins in Uttarakhand. The relevant information in this regard is given in ***Table 3.***

Table 3: Geology and Basin wise breakup of the existing Ground Water Monitoring Stations in Uttarakhand State (as on January 2017)

River Basin/ Sub Basin	*Geology*	*Well No. & Location*
DEHRADUN DISTRICT		
Yamuna Basin, Tons Sub-basin	Doon Gravels (bouldery formation)	DDN-04 (Rampura), DDN-05 (Kuanwala), DDN-06 (Herbertpur), DDN-07 (Jhajra), DDN-08 (Lal Tappar), DDN-09 (Motichur), DDN-10 (Nanda ki Chowki), DDN-11 (Selaqui), DDN-18 (Kanwali), DDN-19 (Chhorba), DDN-20 (Shankarpur), DDN-21 (Judli), DDN-22 (Dandi), DDN-PZ1 (Chhorba), DDN-PZ2 (CGWB Office), DDN-HP-1 (Jhajra), DDN-HP-2 (Redapur), DDN-HP-3 (Majra), DDN-HP-4 (Bhaniawala), DDN-HP-5 (Balliwala), DDN-HP-6 (Harbanswala), DDN-HP-7 (TarlaNagal), DDN-HP-8 (Nanurkhera), DDN-HP-9 (Nanda Ki Chowki), DDN-HP-10 (Selaqui), DDN-HP-11 (Badripur), DDN-HP-12 (Baronwala), DDN-HP-13 (Kuanwala), DDN-HP-17 (Gularghati), DDN-HP-18 (Vikas Nagar), DDN-HP-19 (Khandgaon), DDN-HP-20 (Lal Tappar), DDN-HP-21 (Kotimaichak), DDN-HP-23 (KhadiriKhadakmap), DDN-HP-24 (Dudhli), DDN-HP-25 (Dakpatthar), DDN-HP-26 (Barothiwala), DDN-HP-27 (Dhakrani), DDN-HP-28 (Timli), DDN-HP-35 (Mathrowala), DDN-HP-33 (Telpura), DDN-HP-31 (Baronwala), DDN-32 (Baluwala), DDN-DW-30 (Haripur), DDN-HP-36 (Chandmari), DDN-DW-23 (Duggiawala), DDN-HP-37 (Chhorba), DDN-DW-13 (Dharmawal)
	Doon Gravels (bouldery formation) and Upper Siwaliks (conglomerate, pebbly sands, clay)	DDN-12 (Redapur), DDN-14A (Sabhawala), DDN-15 (Singhniwala), DDN-16 (Ramgarh), DDN-SP2 (Khandoli), DDN-HP16 (Maldeota), DDN-HP22 (Soda Sarauli), DDN-SP3 (Soda Sarauli), DDN-DW-16A(Ramgarh)
	Blaini – Krol, boulder beds	DDN-03 (Rishikesh), DDN-SP1 (Bhatta), DDN-HP-14 (Rishikesh), DDN-HP-15 (Purukulgaon)
HARIDWAR DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Tarai (gravel, sand and clay)	HRW-07 (Bahadrabad), HRW-08 (Missarpur), HRW-09 (Dhanpura), HRW-10 (Hussainpur), HRW-11 (Budhwa Shahid), HRW-12 (Shahidwala Grant), HRW-14 (Rathaura), HRW-15 (Sarai), HRW-16 (Librahedi), HRW-PZ1 (Roorkee), HRW-PZ2

		(Chudiala), HRW-HP-1 (Bhagwanpur), HRW-HP-2 (Bahabalpur), HRW-HP-3 (Jhabrera), HRW-HP-4 (Iqbalpur), HRW-HP-5 (Bugawala), HRW-HP-6 (ShahpurShitlakhera), HRW-HP-7 (Khanpur), HRW-HP-8 (Lakhnauta), HRW-HP-9 (Gurukul Narsen), HRW-HP-10 (Manglaur), HRW-HP-11 (Dallawala), HRW-HP-12 (Govardhanpur), HRW-HP-13 (Dhanpura), HRW-HP-14 (Bhikkampur), HRW-HP-15 (Bahadrabad), HRW-HP-16 (Chudiala), HRW-HP-17 (Shahidwala Grant), HRW-HP-18 (Imlikhera), HRW-HP-19 (Landhaura), HRW-HP-20 (Bhopatwala), HRW-HP-22 (Mudlana), HRW-HP-23 (Bhogpur), HRW-HP-24 (Sultanpur), HRW-HP-25(Kotamuradnagar), HRW-HP-26 (Laksar, HRW-HP-24 (Dudhadyalwala), HRW-HP-25 (Syampur), HRW-DW-16 (Teliwala), HRW-DW-17 (Sikhar), HRW-DW-18 (Kherajat), HRW-DW-19 (Nijampur), HRW-DW-20 (Ambkhera), HRW-DW-21 (Mohamadpur), HRW-DW-23 (Jaswawala), HRW-DW-24 (Kota Muradnagar)
	Siwaliks (sandstone, siltstone, conglomerate)	HRW-13 (Bandarjud), HRW-HP-21 (Laldhang)
UDHAM SINGH NAGAR DISTRICT		
Ganga basin, Ramganga Sub- basin	Tarai (gravel, sand and clay)	USN-01A (Kashipur), USN-02 (Khatima), USN-03 (Bazpur), USN-06A (Sitarganj), USN-07 (Bara), USN-08 (Beria Daulat), USN-09 (Jaspur), USN-11 (Angadpur), USN-12 (Patrampur), USN-13 (Bharatpur), USN-15 (BarkharePande), USN-18 (Banna Khera), USN-19 (Shantipuri), USN-20 (Nanak Mata), USN-21 (Chakarpur), USN-HP-1 (KamariaPakki), USN-HP-2 (Gangapur), USN-HP-3 (Bhagwanpur), USN-HP-4 (Beria Daulat), USN-HP-6 (Jogipura), USN-HP-9 (Majhola), USN-HP-10 (Dhanauri Patti), USN-HP-11 (Kalyanpur), USN-HP-12 (Patthar Chatta), USN-HP-13 (BarkharePande), USN-HP-14 (Sultanpur Patti), USN-HP-15 (Bharatpur), USN-HP-16 (Patrampur), USN-HP-18 (Sitarganj), USN-HP-19A (Kichha), USN-HP-20A (Durgapur), USN-HP-21 (Kopa Signal), USN-HP-22 (Chakarpur), USN-HP-23 (Jharkhandi), USN-HP-24 (Mahabir Nagar), USN-HP-25 (Sarasariya), USN-HP-26 (Rudrapur), USN-HP-28 (Missarwala), USN-HP-29 (Shankhera), USN-HP-30 (Kanaura), USN-HP-31 (Pritpur), USN-HP-32 (Badripur), USN-HP-33 (Pattharpui), USN-HP-34 (Badakhera), USN-HP-35 (Lalpuri), USN-HP-36 (Kanakpur), USN-HP-37 (Rajpura), USN-HP-38 (Pipiliya), USN-HP-39 (Begur Mod), USN-HP-40 (Bidora), USN-HP-41 (Dhyanpur), USN-HP-42 (Barianjaniya)

NAINITAL DISTRICT		
Ganga basin, Ramganga Sub- basin	Bhabar (boulders, gravel, sand and clay)	NTL-03 (Lalkuan), NTL-05 (Maldhan Colony), NTL-HP-1 (Ramnagar), NTL-HP-2 (Belparao), NTL-HP-3 (Dhela), NTL-HP-4 (PeeruMadara), NTL-HP-5 (Dhoniya), NTL-HP-6 (Lamachaur), NTL-HP-7 (Kaladhungi), NTL-HP-8 (Kathgodham), NTL-HP-9 (Sitapur), NTL-HP-10 (Khat Baas), NTL-HP-11 (Chilkiya), NTL-HP-12 (Chanda Devi Amratpur)
	Middle Siwaliks (sandstone with minor clay)	NTL04 (Garjiya), NTL-S1 (Dogaon), NTL-S3 (Garampani), NTL-S4 (Salari), NTL-S5 (Ranibagh), NTL-S6 (Jyolikote)
	Blaini-Krol, boulder beds	NTL-S2 (Sipahidhara), NTL-S7 (Kuda Ghat)
CHAMPAWAT DISTRICT		
Ganga basin, Ramganga Sub- basin	Bhabar (boulders, gravel, sand and clay)	CPT-01 (Tanakpur), CPT-HP-1 (Banbasa)
	Middle Siwaliks	CPT-HP-2 (Bastia), CPT-HP-3 (Bichayee)
	Lesser Himalaya	CPT-SP-1 (Lohaghat)
ALMORA DISTRICT		
Ganga basin, Ramganga Sub- basin	Almora – Ramgarh Formation	ALM-S-1 (PataliTalla), ALM-S-2 (PataliMalla), ALM-S-3 (Katarmal), ALM-S-4 (Dharanaula), ALM-S-5 (Palna), ALM-S-6 (Chinoda), ALM-S-7 (Guruda-I), ALM-S-8 (Guruda-II), ALM-S-9 (Dhansari), ALM-S-10 (Someshwar), ALM-S-11 (Dharanaula Zoo), ALM-S-12 (Bachuradi), ALM-S-13 (Deepakot), ALM-S-14 (Ramgath), ALM-S-15 (Bhagtola),ALM-S-16 (Itola), ALM-S-17 (Potasarain), ALM-S-18 ChhaniBartola), ALM-S-19 (Lodh), ALM-S-21 (Dhalnagaon), ALM-S-22 (Semalkhet), ALM-S-23 (Naula), ALM-S-24 (Bania Diggi)
PAURI GARHWAL DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Bhabar (boulders, gravel, sand and clay)	PG-HP-1 (Kaudiya)
UTTARKASHI DISTRICT		
Ganga Basin, Upper Ganga Sub-basin	Lesser Himalaya	UK-HP-1 (Chinyalisaur), UK-HP-2 (Devidhar), UK-HP-3 (Uttarkashi), UK-HP-4 (Barkot), UK-HP-5 (Sharukhet), UK-HP-6 (Ganeshpur), UK-HP-7 (Maneri), UK-SP-1 (Dharasu), UK-SP-2 (Nagal), UK-SP-3 (Ratodisar)

DEHRADUN DISTRICT

1. Rishikesh 2. Rampura 3. Kuanwala 4. Herbertpur 5. Motichur 6. Sabhawala 7. Singhniwala 8. Ramgarh 9. Kanwali 10. Chhorba 11. Shankarpur 12. Judli 13. Jhajra 14. Redapur 15. Majra 16. Bhaniawala 17. Balliwala 18. Harbanswala 19. Tarla Nagal 20. Nanurkhera 21. Chhorba Pz 22. Nanda Ki Chowki 23. Selaqui 24. Baronwala 25. Kuanwala 26. Rishikesh 27. Purukulgaon 28. Maldeota 29. Gularghati 30. Vikas Nagar 31. Khandgaon 32. Lal Tappar 33. Kotimaichak 34. Soda Sarauli 35. CGWB Office 36. Dandi 37. Khadakmap 38. Dudhli 39. Bhatta Sp 40. Khandoli Sp 41. Soda Sarauli Sp 42. Dakpatthar 43. Barothiwala 44. Dhakrani 45. Badripur 46. Timli

HARIDWAR DISTRICT

47. Bahadrabad 48. Dhanpura 49. Hussainpur 50. Roorkee 51. Bhagwanpur 52. Chudiala 53. Bahabalpur 54. Jhabrera 55. Iqbalpur 56. Bugawala 57. Shahidwala Grant 58. Bandarjud 59. Rathaura 60. Sarai 61. Shahpur Shitlakhera 62. Khanpur 63. Lakhnauta 64. Chudiala 65. Gurukul Narsan 66. Manglaur 67. Dallawala 68. Govardhanpur 69. Bhikkampur 70. Imlikhera 71. Landhaura 72. Bhopatwala 73. Laldhang

PAURI GARHWAL DISTRICT

74. Kaudiya

UDHAM SINGH NAGAR DISTRICT

75. Kashipur 76. Khatima 77. Bazpur 78. Kichha 79. Sitarganj 80. Bara 81. Beria Daulat 82. Jaspur 83. Chakarpur 84. Dhanauri Patti 85. Kalyanpur 86. Patthar Chatta 87. Angadpur 88. Patrampur 89. Bharatpur 90. Barkhare Pande 91. Barhini 92. Sultanpur Patti 93. Banna Khera 94. Shantipuri 95. Nanak Mata 96. Kamaria Pakki 97. Gangapur 98. Bhagwanpur 99. Mahabir Nagar 100. Jogipura 101. Jhagarpuri 102. Majhola 103. Jharkhandi 104. Tukri 105. Sarasariya 106. Durgapur 107. Kopa Signal 108. Rudrapur

NAINITAL DISTRICT

110. Lalkuan 111. Garjia 112. Maldhan Colony 113. Ramnagar 114. Belparao 115. Dhela 116. Peeru Madara 117. Dohniya 118. Lamachaur 119. Kaladhungi 120. Kathgodham 121. Sitapur 122. Khat Baas 123. Dogaon 124. Sipahidhara 125. Garampani 126. Salari 127. Ranibagh 128. Jyolikote

CHAMPAWAT DISTRICT

129. Banbasa 130. Tanakpur 131. Bastia

ALMORA DISTRICT

132. Patli Talla 133. Patli Malla 134. Katarmal 135. Dharanaula 136. Dharanaula Zoo 137. Palna 138. Chinoda 139. Guruda-I 140. Guruda-II 141. Bachuradi 142. Someshwar 143. Dhansari 144. Deepakot 145. Ramgath 146. Bhagtola

UTTARKASHI DISTRICT

147. Chinyalisaur 148. Devidhar 149. Uttarkashi 150. Dharasu 151. Barkot 152. Sherukhet 153. Ganeshpur 154. Maneri 155. Nagal 156. Ratodi Sar

Figure 1 Location of Ground Water Monitoring Stations in Uttarakhand (As on March 2018)

CHAPTER – 2

CLIMATE

The hilly parts of Uttarakhand experience cold climate and high rainfall. Significantly large part of the state remains under snow cover throughout the year. The intermontane valleys and the plain area in the southern part of the state experience a sub tropical climate with three seasons – summer, monsoon and winter. The normal annual rainfall varies from 1256 mm in Haridwar district to 2426 mm in Pithoragarh district. The average annual rainfall varies from 927.7 mm at Joshimath (Chamoli district) to 2599.4 mm at Munsyari (Pithoragarh district). Most of the rainfall occurs as monsoon rainfall during the months of July and August. The Isohyetal Map of Uttarakhand prepared using mean normal rainfall is given in **Fig. 2**. The map reveals that intensity of rainfall increases from SW to NW in a broadly linear pattern with high rainfall prevailing in both the eastern and the western parts of the state. The district wise normal monthly and annual rainfall data, available for seventy years (1901 to 1970) is given in **Table 4.**

Table 4: District wise normal monthly and annual rainfall (mm) in Uttarakhand State (1901-1970)

District	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annual*
Dehradun	57.4	55.8	37.6	17.1	34.0	178.9	686.9	751.5	314.5	47.1	7.8	37.4	2212.0
Chamoli	103.0	107.8	114.5	57.2	47.9	117.1	314.4	322.0	169.0	51.4	23.5	47.0	1474.8
Nainital	37.7	33.4	18.7	8.6	27.2	173.6	466.2	454.7	239.7	52.2	3.9	11.9	1527.8
Pithoragarh	257.8	193.4	190.9	78.2	70.9	239.4	496.7	441.8	290.9	57.2	32.4	76.3	2425.9
Haridwar	48.1	45.8	24.5	9.8	19.9	108.9	360.1	393.8	190.2	34.3	5.4	15.4	1256.2
Tehri Garhwal	64.1	50.5	57.5	25.9	47.0	120.7	374.3	339.8	207.2	62.5	10.6	34.5	1394.6
Uttarkashi	102.4	59.2	90.4	46.6	72.7	128.8	400.3	426.5	301.4	46.9	20.4	36.5	1732.1
Almora	54.8	56.5	49.8	32.4	56.8	162.4	345.5	321.5	165.5	56.0	7.5	21.6	1330.3
Pauri Garhwal	58.9	59.8	41.9	23.5	45.0	151.4	412.9	402.5	188.9	43.7	6.8	23.0	1458.4

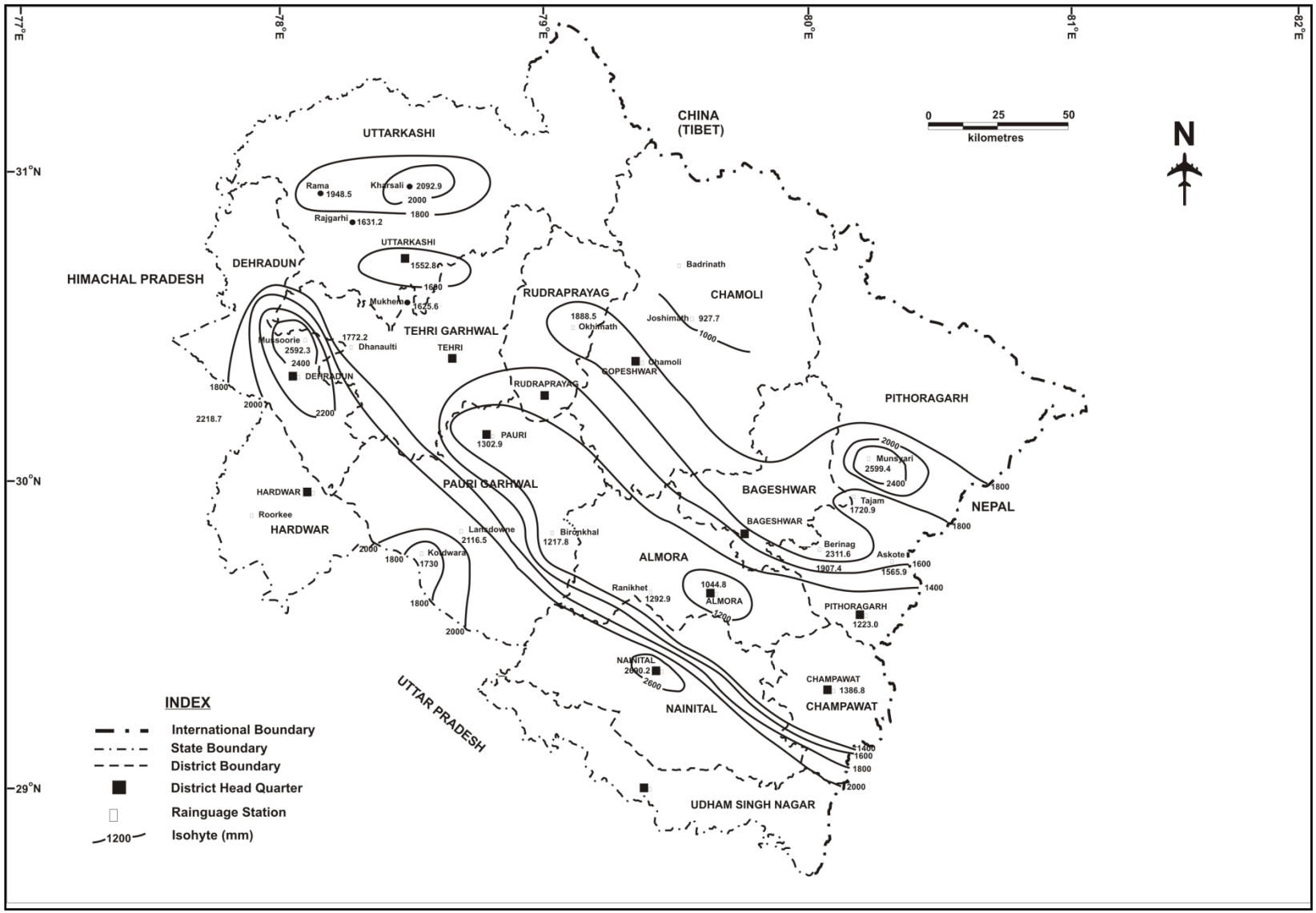


Figure 2 Mean Annual Isohyetal Map, Uttarakhand State

CHAPTER – 3

GEOLOGY

The state of Uttarakhand has distinct geological attributes with a wide spectrum of rock types ranging in age from Achaean to Quaternary. Based on the diversity of geological processes in time and space, the state can be subdivided into two major physiographic-cum-tectonic units, viz.

1) Gangetic Alluvial Plain
2) Himalayan Mountain Belt.

A brief description of the geology of Uttarakhand is given below.

1. Gangetic Alluvial Plain

Gangetic Alluvial Plain, a part of the Indo-Gangetic Foreland Basin, occupies the southernmost part of the state. This zone consists of Quaternary fluvial sediments also known as Ganga Alluvium. Subsurface investigations in this belt have revealed a thick pile of alluvium resting conformably over the Siwalik succession of Neogene to early Pleistocene Period. The thickness of alluvium increases towards north and attains its maximum adjacent to the *Foot Hill Fault* (FHF), which marks the northern limit of the youngest foreland basin in India i.e. the Ganga Fore deep Basin. The Ganga Fore deep sediments extend up to the south of depositional boundary of the Siwalik succession and rests over Precambrian cratonic rocks of Peninsular Indian Shield.

2. Himalayan Mountain Belt (Extra Peninsular Belt)

The Himalayan Mountain Belt is a part of the global mobile belt of Mesozoic to Cenozoic age that is believed to have evolved through the convergence of active Indian Plate and passive Eurasian Plate during the continent-continent lithospheric collision. Late Proterozoic (Neoproterozoic) to early Cenozoic crustal sequences form a small part of Himalaya, whereas the main mountain chain consisting predominantly of Proterozoic rocks represents a part of the Indian Shield. The Proterozoic crystalline rocks have been affected by various orogenic episodes of Mesozoic to Cenozoic Period and show signs of multiple phases of deformation and metamorphism. The Extra-Peninsular region has a wide spectrum of rocks of sedimentary, metamorphic and igneous origin.

Uttarakhand State is a part of Western Himalaya. Four distinct tectonic zones, each characterized by specific geological attributes and bounded by prominent dislocation zones can be recognized in Uttarakhand Himalaya from south to north. A brief description of the zones is given below:

2.1. Outer Himalaya or Sub Himalaya

This zone constitutes of a thick Cenozoic sedimentary pile ranging in age from Paleocene to Upper Pleistocene. Its northern and southern boundaries are delimited by the *Main Boundary Thrust* (MBT) and the *Foot Hill Fault* (FHF) also known as the *Main Frontal Thrust* (MFT), respectively. This zone consists predominantly of continental molasses sediments of Siwalik Group ranging in age from Middle Miocene to Upper Pleistocene. The Siwalik Group has been subdivided into the Lower Siwalik, Middle Siwalik and Upper Siwalik. The Lower Siwalik consists of fine to medium grained sandstone with clay, the Middle Siwalik is formed of medium grained sandstone with calcareous concretions and sandy clay and the Upper Siwalik consists predominantly of conglomerate with lenticular outcrops of sandstone and minor clay. The elevation of this

zone ranges from 250 to 800 m above mean sea level and width varies from 25 to 100 km. This zone is also characterized by a number of flat-floored structural valleys such as the *Doon Valley.*

2.2. Lesser Himalaya

The litho units lying between the Main Boundary Thrust (MBT) in the south and the *Main Central Thrust* (MCT) in the north are included under the Lesser Himalayan Zone, which has the greatest exposed width of about 80 km in the Garhwal and Kumaun regions of Uttarakhand. The rocks of this zone are overlain by crystalline thrust sheets in the form of large klippen masses occupying mostly the higher topographical levels of the mountain ranges. Regionally metamorphosed Proterozoic rocks emplaced by granites of variable ages along with weakly metamorphosed to unmetamorphosed sedimentary rocks (quartzites with interbedded volcanics, carbonates associated with slate, quartzite and shale) occur extensively in this zone. The granitoids are associated with volcano sedimentary sequence (Bhimtal Formation) and are emplaced along with the predominantly metamorphic and metasedimentary rocks of this zone, forming large-scale nappes like the Almora-Ramgarh nappe, Baijnath-Askot nappe and Garhwal nappe.

2.3. Central or Higher Himalaya

This zone consists of thick slabs of Proterozoic crystalline rocks, which thrust southward along the *Main Central Thrust* (MCT), over-riding the Lesser Himalayan Zone. This zone is a 10-15 km wide sequence of metamorphic rocks and granites. This zone represents the Proterozoic basement that has been reactivated due to crustal shortening during the continent-continent collision of the Himalayan Orogeny. The metamorphic rocks exposed in this zone show progressive regional metamorphism ranging from green schist facies to upper amphibolite facies. Both foliated and non-foliated granitoids are emplaced in different structural and tectonic levels within the regionally metamorphosed crystallines.

2.4. Tethys Himalaya

This zone is occupied by the thick sedimentary sequence ranging in age from Late Precambrian (Neoproterozoic) to Lower Eocene. Sediments of marine facies, characteristic of continental shelf to continental slope environments of the Tethys Sea regime, are the predominant litho types of this zone. In Uttarakhand, this zone is well exposed in the Zanskar Mountains and mountain ranges of Kumaun region. This zone is separated from the Central Crystallines by Dar-Martoli Fault, with the Lower Martoli Formation representing the base of Phanerozoic, which is broadly folded and faulted with several local thrusts. The rock sequence comprises phyllite, mica schist and quartzite with lenticular outcrops of limestone.

CHAPTER – 4

HYDROGEOLOGY

Uttarakhand State has a very diverse hydrogeological set-up. However, thishilly state can broadly be classified into two hydrogeological regimes namely Gangetic Alluvial Plain and Himalayan Mountain Belt. The description of these two types of hydrogeological-cum-physiographic units with further subdivisions is given below:

1. Gangetic Alluvial Plain

The Gangetic Alluvial Plain is a vast expanse of alluvium of Tertiary and Quaternary age. Alluvium is a generalized term for detrital unconsolidated sediments comprising predominantly of clay, silt, sand and gravels formed on river beds, flood plains, alluvial fans etc. This zone is very promising from the hydrogeological point of view having substantial water resource. This unit can be subdivided into three distinct hydrogeological regimes from south to north, viz. Axial Belt, Tarai and Bhabar.

1.1. Axial Belt

This unit, also called as the Alluvial Plains, is demarcated by the termination of alluvial fans that grade further down slope into vast alluvial plains. This zone is composed of a mixture of gravel, sand, silt and clay deposited in alternating layers. The aquifers present in this zone are of unconfined to confined nature. The area, in general, has good ground water resource potential but overexploitation of ground water reserve at places has resulted in the decline of water levels and needs implementation of artificial recharge methods. Drilling in this zone can be best accomplished by Rotary Drilling method having high drilling rate and hence, requiring less time for drilling.

1.2. Tarai

This is a generalised term for a sedimentary unit consisting of a mixture of gravel, sand and clay (sometimes also referred to as Tarai Formation). The boundary between Tarai and Bhabar is demarcated by the presence of springs forming a linear pattern, thus delineating a "spring line". Due to the highly porous and permeable nature of the constituting material of sedimentary origin, many potential aquifers having groundwater of good chemical quality exist in this area. Two types of aquifers can be found in this zone –

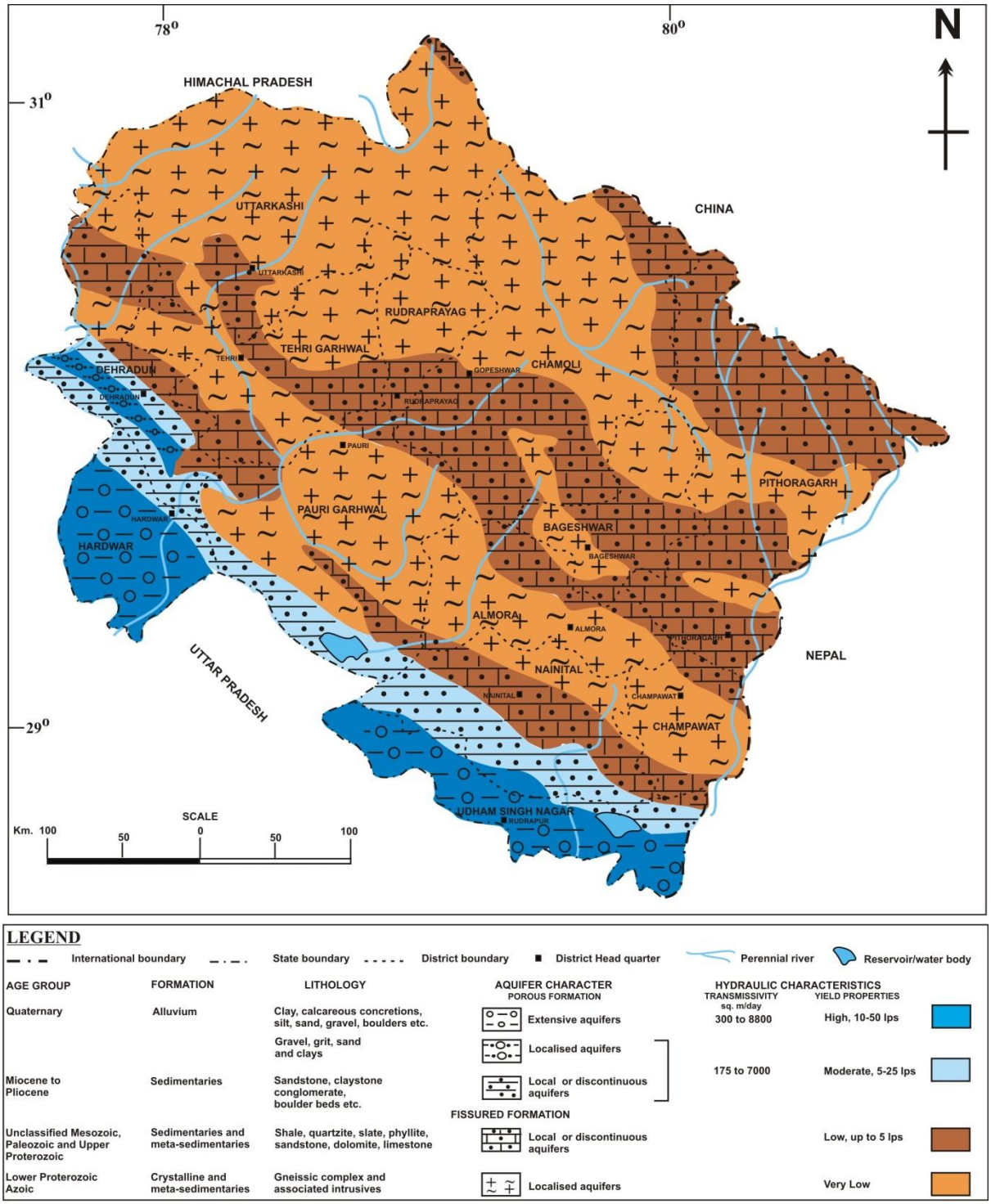
a) Unconfined Aquifers down to depths of 30 meters below ground level (m bgl) and
b) Confined Aquifers that occur at depths greater than 30 m bgl under very high hydrostatic pressure.

The tubewells are tapping these aquifers generally exhibit free flowing conditions with hydraulic head sometimes as high as 10 m agl and discharge of 5000 lpm.

1.3. Bhabar

A mixture of clastic material having different size fractions (e.g. boulder, pebble, gravel, sand, silt and clay) constitutes this unit, which is also referred to as Bhabar Formation. Bhabar zone is also a promising hydrogeological entity though the occurrence of ground water at deeper levels (generally greater than 100 m bgl) poses a

problem for ground water exploitation. Central Ground Water Board has constructed 28 deep tube wells (with discharge as high as 5540 lpm) by percussion drilling method in this zone of the state. Perched water bodies having smaller water resource potential are frequently encountered in this zone.



LEGEND

International boundary — State boundary — District boundary — District Head quarter — Perennial river — Reservoir/water body

AGE GROUP	FORMATION	LITHOLOGY	AQUIFER CHARACTER	HYDRAULIC CHARACTERISTICS TRANSMISSIVITY sq. m/day	YIELD PROPERTIES
			POROUS FORMATION		
Quaternary	Alluvium	Clay, calcareous concretions, silt, sand, gravel, boulders etc.	Extensive aquifers	300 to 8800	High, 10-50 lps
		Gravel, grit, sand and clays	Localised aquifers	175 to 7000	Moderate, 5-25 lps
Miocene to Pliocene	Sedimentaries	Sandstone, claystone conglomerate, boulder beds etc.	Local or discontinuous aquifers		
			FISSURED FORMATION		
Unclassified Mesozoic, Paleozoic and Upper Proterozoic	Sedimentaries and meta-sedimentaries	Shale, quartzite, slate, phyllite, sandstone, dolomite, limestone	Local or discontinuous aquifers		Low, up to 5 lps
Lower Proterozoic Azoic	Crystalline and meta-sedimentaries	Gneissic complex and associated intrusives	Localised aquifers		Very Low

Figure 3 Hydrogeological Map of Uttarakhand

2. Himalayan Mountain Belt

This is a part of the Alpine-Himalayan Mountain Chain and constitutes a major part of the total geographical area of Uttarakhand. This zone is also known as Extra-Peninsular Region. The belt trends northwest – southeast with roughly parallel mountain ranges spanning across the state. This region can be further subdivided into five tectonic units from south to north. These units are Outer Himalaya, Lesser Himalaya, Central Himalaya, Tethyan Himalaya and Indus Suture Zone. However, the

Indus Suture Zone does not fall within the geographical area of Uttarakhand State. A brief description of the remaining four units that falls in the state is as follows:

2.1. Outer Himalaya (Siwalik Mountain Range)

This unit is composed dominantly of sandstone, ferruginous shale and clay and is younger in age as compared to the other units of the belt. The general elevation of the zone is less than 1000 m above mean sea level. Due to the semi-consolidated nature of rocks, potential ground water bearing formations are present in areas, which have a good weathered mantle and highly fractured/jointed rocks. In the Siwaliks, a number of valleys have also been developed as a result of tectonic activities (e. g. Doon Valley), which are very important from the hydrogeological point of view. The Doon Valley was formed as an *Intermontane Valley* within the Siwalik Group of rocks in a foreland propagating thrust system. The Lower, Middle and Upper Siwaliks are exposed in the area, and the Doon Gravels, a post-Siwalik Formation, were deposited with the evolution of the valley. The Doon Gravels are thickly bedded coarse clastic fan deposit of late Pleistocene and Holocene age. The Central Ground Water Board has successfully constructed 11 deep tubewells, with discharge ranging from 252 to 3197 lpm in the Doon Valley of Dehradun district. The water levels in these aquifers range from 20 m bgl in the southern part of the valley to about 100 m bgl in the northern part.

2.2. Lesser Himalaya

This zone is represented by mountains bounded by Main Boundary Thrust (MBT) in the south and Main Central Thrust (MCT) in the north having an elevation ranging between 1000 and 3000 m above mean sea level. This unit is dominantly composed of metasedimentary rocks and minor plutonic intrusives (granitoids). Springs form the most important source of ground water in this zone. In these formations ground water occurrence is restricted to the weathered residuum and the highly fractured/jointed zones of the area. Several hand pumps have been installed successfully in this zone. At a few places, especially in the river valleys, tubewells having low to moderate discharges have also been successfully constructed.

2.3. Central Himalaya

The Central Himalayan zone lies to the north of *Main Central Thrust* (MCT) with an elevation ranging from 5000 to 8000 m above mean sea level. Both cold water and hot water (thermal) springs are present in this zone. So far a total of 25 thermal springs have been investigated with temperatures ranging from 32°C to 70°C and discharge varying between 60 to 600 lpm, corresponding to 5^{th} order and 4^{th} order as per Meinzer's Classification of spring discharge. Due to highly inaccessible, snow-covered areas in this zone and a very steep hydraulic gradient, the possibility of ground water development is almost negligible.

2.4. Tethys Himalaya

Situated to the north of Central Himalayan zone, this zone is predominantly occupied by the highly fossiliferous sedimentary rocks ranging in age from Precambrian to Jurassic. Due to the porous and permeable nature of the litho units, this zone is generally suitable for ground water development.

CHAPTER – 5

BEHAVIOUR OF WATER LEVEL

The water levels of Ground Water Monitoring Wells of Uttarakhand were measured four times during the period 2016-2017 (May, August, November 2016 and January 2017). The water levels observed are shown in Table 5. The ground water levels in different seasons were analyzed to evaluate the temporal behaviour of water level. The behaviour of water levels in each season during the period May 2016 – January 2017 has been compared with the water levels of previous year as well as with average water level for the last decade to ascertain the changes in ground water regime.

Apart from this, the fluctuation of water levels during the current year and previous year has also been evaluated in order to assess the adverse impact on hydrogeological regime, if any.

Table 5: Water level data of Ground Water Monitoring Wells, Uttarakhand State

SL. No.	Location	May-16	Aug-16	Nov-16	Jan-17
DEHRADUN DISTRICT					
Raipur block					
1	Kanwali	14.22	8.34	12.45	13.2
2	CGWB Office	63.28	62.08	57.34	57.51
3	Tarla Nagal	77.42	70.4	71.7	73.65
4	Majra	27.16	25.59	31.1	7.79
5	Balliwala	58.4	58.21	67.18	58
6	Harbanswala	61.85	52.27	67.48	62.05
7	Tarla Nagal	56.17	61.31	63.16	52.97
8	Nanurkhera	71.4	59.56	63.19	59.98
9	Kuanwala	15.96	4.91	8.16	11.95
10	Purukulgaon	29.14	14.44	12.48	26.48
11	Maldeota	13.25	4.78	9.98	13.73
12	Gularghati	6.28	7.97	11.29	12.66
13	Soda Sarauli	5.21	5.76	6.54	5.61
14	Ladpur Pz*	NA	85.32	NA	85.65
Doiwala block					
15	Rishikesh DW	14.12	16.29	12.66	13.32
16	Rishikesh HP	5.21	5.76	6.54	5.61
17	Lal Tappar	17.2	16.03	16.05	14.82
18	Motichur	13.64	4.08	10.48	11.03
19	Dandi	3.85	4.66	5.06	6.06
20	Khandgaon	9.15	5.16	4.61	8.97
21	Kotimaichak	18.65	12.76	15.97	19.72
22	Khadak Maaf	16.22	7.97	15.27	14.03
23	Bhaniawala	22.3	14.6	16.73	29.36
24	Duggiawala DW	7.2	5.69	6.91	2.1
25	Mathrowala HP	10.7	8.34	9.9	10.31
26	Chandmari HP	32.57	26.93	27.31	29.96

Sahaspur block					
27	Rampura	12.35	7.24	9.72	9.62
28	Jhajra DW	12.58	NA	NA	16.14
29	Jhajra HP	14.8	7.08	8.46	12.72
30	Selakui DW	11.77	7.61	9.12	9.79
31	Selakui HP	15.77	12.61	12.44	12.37
32	Nanda Ki Chowki DW	12.98	8.24	8.04	12.1
33	Nanda Ki Chowki HP	15.93	11.02	11.77	13.9
34	Redapur DW	7.87	4.44	NA	5.19
35	Redapur HP	9.55	8.08	9.4	7.47
36	Shankarpur	24.67	23.86	23.18	25
37	Chhorba DW	17.35	NA	NA	NA
38	Chhorba PZ	71.74	NA	NA	NA
39	Baronwala HP	28.58	26.07	27.26	23.9
40	Chhorba HP	38.75	39.21	42.43	32.13
41	Telpura HP	37.2	40.72	43.4	38.52
42	Sahaspur HP	11.8	8.54	16.96	16.9
Vikas Nagar block					
43	Herbertpur	9.61	7.45	9.77	10.1
44	Dharmawala	7.1	NA	3.94	5.9
45	Sabhawala	9.7	5.32	8.29	14.92
46	Singhniwala	9.76	8.84	8.41	6.64
47	Ramgarh	7.74	5.32	5.99	6.3
48	Judli	13.9	11.86	13.56	13.4
49	Badripur	9.4	7.47	8.57	12.03
50	Vikas Nagar	24.03	22.78	26.76	27.33
51	Dak Patthar	28.59	22.93	25.79	26.57
52	Barotiwala	30.94	20.64	22.56	NA
53	Dhakrani	17.52	11.44	13.36	21.28
54	Timli	NA	56.56	66.78	62.95
55	Baluwala HP	30.87	39.06	41.77	36.8
56	Luxmipur HP	31.54	28.96	NA	28.84
HARIDWAR DISTRICT					
Bahadrabad block					
1	Bahadrabad	9.12	16.69	12.17	11.66
2	Dhanpura	8.66	4.39	7.72	6.64
3	Bandarjud	8.11	7.01	8.4	9.6
4	Rathaura	2.8	4.29	4.66	4.85
5	Sarai	13.74	9.88	12.53	13.16
6	Shahpur Shitlakhera	6.82	2.93	5.2	4.86
7	Laldhang	69.22	59.58	66.18	61.57
8	Panjanheri	7.52	4.47	5.52	7.58
9	Dudhya Dayalwala	3.6	2.67	2.43	2.79
10	Shyampur	9.89	8.67	10.04	10.75
11	Jaswawala	5.5	2.98	3.68	3.93
12	Dalupuri DW	30.08	27.23	NA	26.49

Bhagwanpur block					
13	Budhwa Shahid	4.95	2.48	3.93	3.82
14	Shahidwala Grant DW	12.8	9.68	9.96	11.2
15	Shahidwala Grant HP	10.7	8.68	9.62	10.02
16	Bhagwanpur	13.62	15.61	8.99	12.13
17	Bahabalpur	3.8	2.07	2.81	2.52
18	Iqbalpur	10.58	13.32	13.75	13.17
19	Bugawala	NA	11.35	6.65	6.67
20	Chudiala HP	12.14	12.38	15.33	20.18
21	Kota Muradnagar DW	13.77	NA	NA	NA
22	Kota Muradnagar HP	7.6	9.41	11.22	9.9
Roorkee block					
23	Roorkee	7.84	5.12	6.27	6.38
24	Imlikhera	15.2	16.02	17.45	15.46
25	Nijampur	10.11	10.37	10.46	10.72
26	Ambkheri	3.3	NA	NA	NA
27	Landhaura	18.42	17.09	11.72	18.15
Laksar block					
28	Hussainpur	4.56	1.21	2.3	2.17
29	Bhikkampur	2.82	1.02	2.37	1.45
30	Laksar	3.78	1.81	2.89	2.92
Narsan block					
31	Jhabrera	10.92	10.61	9.76	10.16
32	Lakhnauta	9.88	6.8	7.14	7.34
33	Gurukul Narsen	8.34	3.76	4.36	6.98
34	Libberhedi	13.29	5.45	6.34	6.85
35	Mundlana	15.25	17.76	17.75	17.96
36	Bhogpur	3.66	1.42	3.78	3.91
37	Sikhar	16.47	17	17	17.16
38	Khera Jat	7.48	5.9	6.08	6.26
Khanpur block					
39	Khanpur	2.96	1.92	2.38	1.48
40	Dallawala	1.72	1.04	1.57	1.59
41	Govardhanpur	3	1.67	2.36	2.09
42	Mohammadpur	1.55	NA	NA	NA
PAURI GARHWAL DISTRICT					
1	Kaudiya (Kotdwar)	55.42	57.68	61.37	57.2
UDHAM SINGH NAGAR DISTRICT					
Jaspur block					
1	Jaspur	15.83	15.06	13.24	13.26
2	Patrampur	9.03	10.58	7.73	8.45
3	Angadpur	5.5	13.12	NA	6.48
4	Durgapur	5.34	3.67	3.36	3.46
5	Missarwala	10.8	10.58	8.2	5.56

Kashipur Block					
6	Barkhare Pande	7.92	6.94	NA	6.88
7	Sultanpur Patti	1.54	1.14	4.24	1.61
8	Kashipur	6.73	4.57	5.16	4.88
9	Bharatpur	9.96	9.1	7.55	7.49
10	Dhannauri Patti	4.46	2.72	3.16	3.12
11	Shankhera	5.08	6.94	4.88	5.57
Bazpur Block					
12	Bazpur	2.93	0.82	2.28	2.16
13	Jharkhandi	1.84	1.74	1.64	1.28
14	Jogipura	4.12	3.62	3.72	2.64
15	Banna Khera	4.6	3.75	3.7	2.22
16	Pritpur	0.65	4.27	3.95	3.83
17	Badripur	NA	4.1	2.6	4.21
Gadarpur Block					
18	Jhagarpuri	3.33	1.63	2.18	3.1
19	Mahabir Nagar	2.12	1.43	2.38	2.51
20	Beria Daulat	4.44	2.08	3.26	3.02
21	Bhagwanpur	7.97	5.76	NA	2.85
22	Pattharpui	4.16	2.41	NA	3.31
23	Badakhera	3.37	NA	NA	NA
24	Lalpuri	2.3	2.12	1.5	1.9
Rudrapur Block					
25	Bara	2.08	0.9	2.52	1.9
26	Kichha HP	5.95	7.77	NA	8.34
27	Kamaria Pakki	6.27	1.52	4.82	4.98
28	Gangapur	3.76	2.58	2.8	2.58
29	Shantipur	1.07	1.18	1.8	1.62
30	Pattar Chatta	3.06	2.1	NA	2.49
31	Rudrapur	2.43	0.9	3.8	3.93
32	Kanakpur	2.55	3.61	2.59	2.61
33	Rajpura	3.46	3.15	NA	2.36
34	Pipiliya	5.62	5.27	3.92	2.78
Sitarganj Block					
35	Sitarganj	3.46	1.28	1.34	2.56
35	Nanak Mata	4.61	2.17	2.89	2.85
36	Kalyanpur	2.71	1.97	4.16	2.46
37	Tukri	4.49	6.42	4.39	2.8
38	Begur Mod	4.92	2.41	3.39	3.46
39	Bidora	4.9	2.96	NA	4.7
40	Dhyanpur	4.47	3.25	2.53	2.01

Khatima Block					
41	Kanchanpur (Majhola)	5.5	3.78	5.1	4.21
42	Khatima	3.25	1.44	2.45	2.61
43	Sara Sariya	3.35	7.53	3.85	4.66
44	Chakarpur	5.87	6.77	2.47	6.49
45	Barianjariya	5.88	2.24	3.95	4.31
NANITAL DISTRICT					
Haldwani Block					
1	Khat Baas	15.61	19.6	30.1	34.88
2	Lalkuan	NA	9.21	NA	10.44
3	Lamachaur	NA	48.68	NA	43.74
4	Kaladungi	31.75	27.05	27.97	29.25
5	Kathgodham	19.34	10.76	17.06	15.89
Ramnagar Block					
6	Belparao	57.46	55.48	61.66	56.51
7	Peeru Madara	27.4	23.7	22.74	23.53
8	Maldhan Colony	1.94	2.88	18.38	4.03
9	Dhela	67.48	69.78	80.98	54.15
10	Ramnagar	10.83	8.98	19.63	6.73
11	Garjia	4.95	3.45	4.00	4.00
12	Dhoniya	37.28	65.78	55.38	65.43
13	Chilkiya	54.78	54.57	52.32	55.2
CHAMPAWAT DISTRICT					
1	Tanakpur	NA	8.65	10.63	10.78
2	Banbasa HP	10.63	NA	NA	4.38
3	Bastia HP	30.44	18.1	NA	39.49
4	Bichayee HP	NA	10.08	9.28	9.76
UTTARKASHI DISTRICT					
1	Chiniyalisaur HP	46.32	26.54	34.06	47.87
2	Devidhar HP	9.97	8.09	12.78	9.07
3	Uttarkashi HP	19.48	14.69	17.98	NA
4	Barkot HP	16.19	15.38	17.31	17.01
5	Serukhet HP	29.32	18.32	22.12	17.5
6	Ganeshpur HP	16.93	14.23	16.91	17.02
7	Maneri HP	15.77	28.03	NA	29.35
8	Charethi HP *	NA	16.99	19.41	24.1

DEPTH TO WATER LEVEL

5.1.1 May 2016

The depth to water level data was analyzed for 155 Ground Water Monitoring Wells in Uttarakhand during May 2016 and is given in ***Table 6.*** Analysis of depth to water level data given in the table indicates that the deepest water level was 77.42 m bgl at Tarla Nagal in Dehradun district whereas the shallowest water level was 0.65 m bgl at Pritpur in Udham Singh Nagar, district. The depth to water level in the range of 0–5 m bgl was recorded in 45 ground water monitoring wells, which is 29.03% of the total number of wells. Water level in the range of 5–10 m bgl was shown by 39 monitoring wells (25.16% of total number), whereas deeper water level of 10–15 m bgl was recorded in 26 monitoring wells, which was 16.77% of the total number. The deepest water level of >15 m bgl was shown by 45 monitoring wells, which is 29.03% of the total monitoring wells in Uttarakhand during May 2016.

Table 6: District wise categorization of depth to water level data, May 2016

District	No. of stations analyzed	Depth to water level (m bgl)		Depth to water level (m bgl)							
				0-5		5-10		10-15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	55	3.85	77.42	1	1.82	13	23.64	13	23.64	28	50.91
Haridwar	41	1.55	69.22	13	31.71	12	29.27	10	24.39	6	14.63
U. S. Nagar	45	0.65	15.83	29	64.44	14	31.11	1	2.22	1	2.22
Nainital	11	1.94	67.48	2	18.18	0	0.00	1	9.09	8	72.73
Champawat	2	10.63	30.44	0	0.00	0	0.00	1	50.00	1	50.00
Pauri Garhwal	1	--	55.42	0	0.00	0	0.00	0	0.00	1	100.00
Total	**155**	**0.65**	**77.42**	**45**	29.03	**39**	25.16	**26**	16.77	**45**	29.03

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for ***May 2016*** is shown in ***Fig. 4*** *(Dehradun, Section),* ***Fig.5*** *(Haridwar section)* and ***Fig. 6*** *(Nainital-Udham Singh Nagar-Champawat Section).*

A study of Fig. 4 indicates that the major part of the Dehradun district shows deeper water levels (more than 15m). The water level in the range of 10-15 m is observed in the form of a narrow band covering north central and central part of Doon valley and also as small patch around the Khadri Khadakmaf & Motichur. The water level in the range of 5-10 m occurs in more or less linear zone in north-central part of Doon gravels

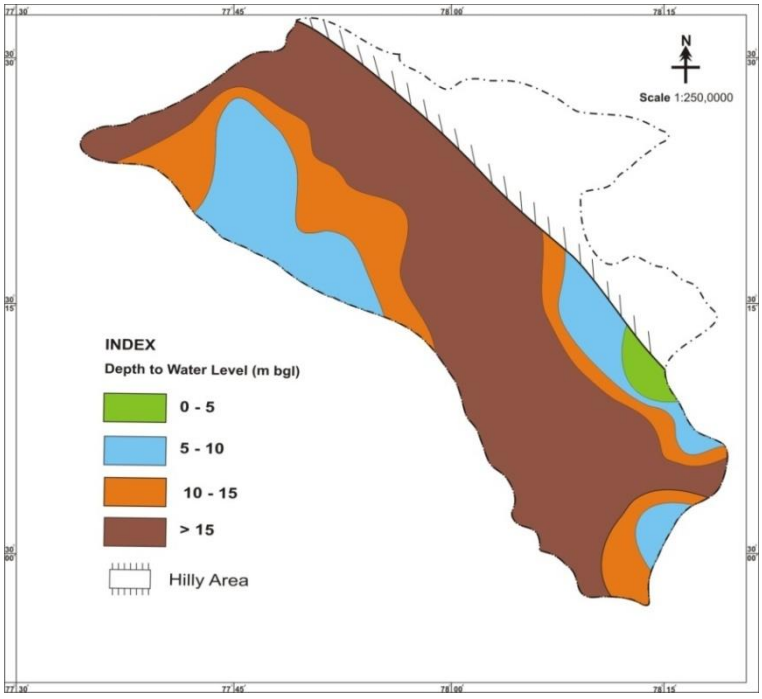


Figure 4 Depth To water Level Map (May 2016), Dehradun District

(Sabhawala – Herbertpur - Redarpur section); also occurs as small isolated patches near Khandgaon. The shallow water levels in the range of 0-5m is observed only at Dandhi.

The visual interpretation of the **Fig. 5** indicates that the shallowest water level in the range of 0-5m occurs mostly in the southern part of the Haridwar district and also as Lenticular patch around Bahabalpur. The shallowest water levels in the range of 5-10m occurs as linear zone trending from south-west to south-east (Lakhnauta - Nizampur-Husainpur - Dhanpura section) and also occurs in northern and north wastern part of the Haridwar district. The water level in the range of 10-15m zone occurs in the broad zone trending from west to east covering majority of central part of Haridwar district. The deepest water level in the range of more than 15m occurs as an isolated patch around the Landhuara- Shikar and Laldhang (which demarcates the Bhabar zone).

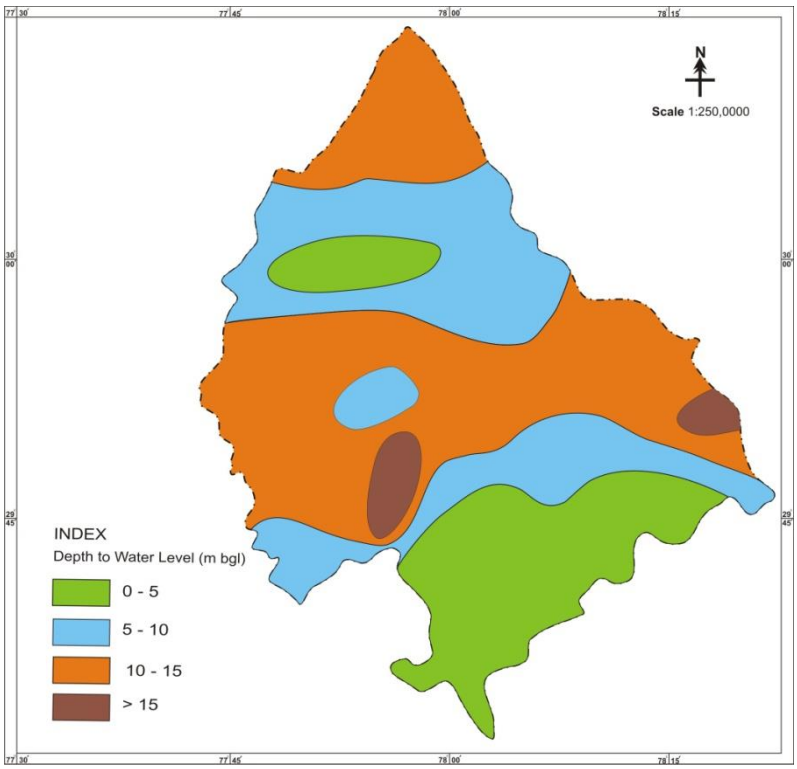


Figure 5 Depth To water Level Map (May 2016), Haridwar District

The visual interpretation of the **Fig. 6** indicates that the shallowest water level i.e. 0-5m observed as long band extending from Maldhan Colony in Nanital district to Dhanauri Patti, Badaripur, Pathar Chatta, Sitarganj, Khatima in Udham Singh Nagar district, and extending upto bastia in Champawat district. The water level in the range of 5-10m is observed around Angadpur – patrampur – Barkhare Pande, Bhagwanpur – Khamaria Pakki – peepli Chauraha in Udham Singh Nagar district and Banbasa in Champawat district. This zone also observed as narrow band running from North Western part of the Nanital district covering central part of district and extending till eastern part of the Champawat district. The water level in the range of 10-15m occurs covering the 5-10 m water levels extending from north western part of the section to eastern part of the section; and also as isolated patch around the Missarwala. The deepest water level (>15 m)is running parallel to the 10-15 m water level zone from north western part of the section continuing upto the Khatbass in the Nanital district; and also as isolated patch around jaspur in the Udham Singh District. In general, it is observed that the water level deepens from south to north in the section.

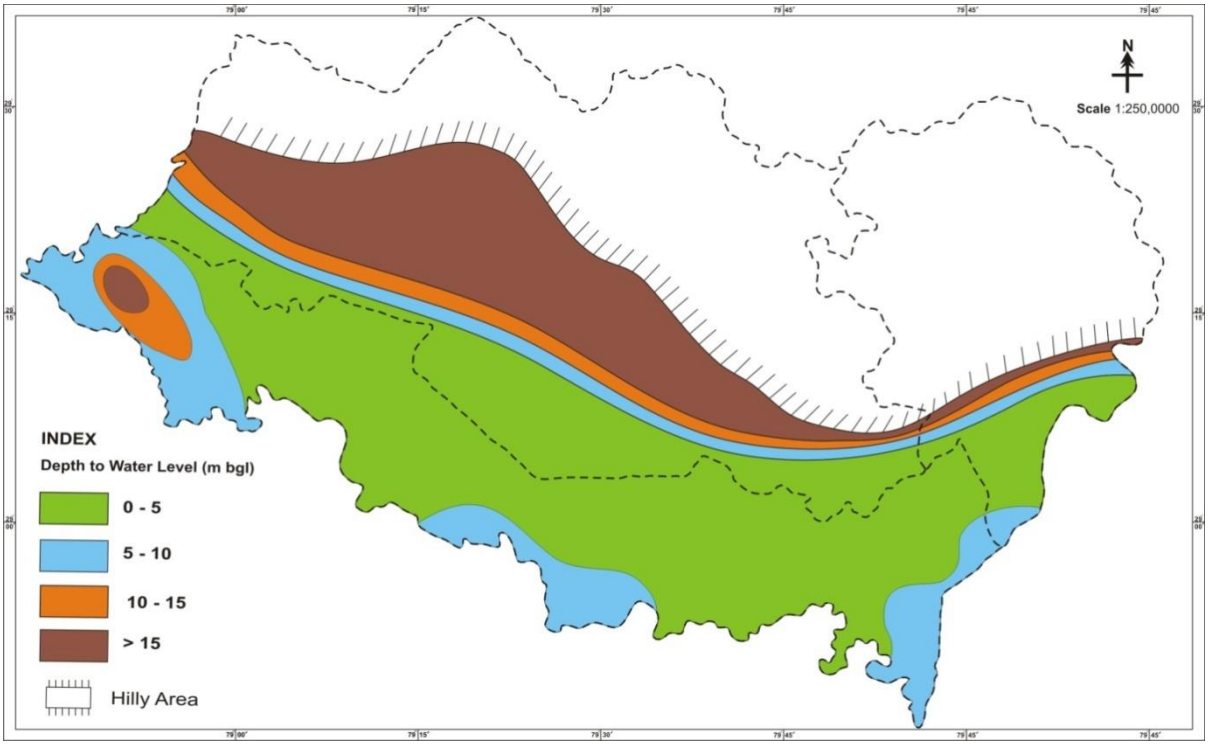


Figure 6 Depth To water Level Map (May 2016), US Nagar – Nainital - Champawat District

5.1.2 August 2016

During the month of August 2016, total of 154 Groundwater monitoring wells (including dug wells, hand pumps and piezometers) were monitoried in Uttarakhand State in District Dehradun, Haridwar, Udham Singh Nagar, Pauri Garhwal, Nainital and Champawat. The depth to water level data has been classified and is given in **Table 7.** A perusal of the table indicates that deepest water level was 85.32 m bgl at Ladpur Piezometer Piezometer in District Dehradun district while the shallowest water level was 0.82 m bgl at Bazpur in Udham Singh Nagar district. The analysis of depth to water level data has also shown that shallowest water level of 0-5 m was recorded by 55 monitoring wells, which was 35.71% of the total number. Depth to water level in the range of 5-10 m was shown by 42 wells (27.27% of total number), whereas the deeper water levels of 10-15 m was shown by 17 wells (11.04% of total) whereas the deepest water levels (>15 m) was recorded by 40 monitoring wells, which was 25.97% of the total number of wells in Uttarakhand monitored during August 2016.

Table 7: District wise categorization of depth to water level data, August 2016

District	*No. of stations analyzed*	*Depth to water level (m bgl)*		**Depth to water level (m bgl)**							
				0- 5		***5-10***		***10-15***		***>15***	
		Min	***Max***	***No.***	***%***	***No.***	***%***	***No.***	***%***	***No.***	***%***
Dehradun	53	4.08	85.32	5	9.43	20	37.74	7	13.21	21	39.62
Haridwar	39	1.02	59.58	16	41.03	10	25.64	5	12.82	8	20.51
Udham Singh Nagar	45	0.82	15.06	32	71.11	9	20.00	3	6.67	1	2.22
Nainital	13	2.88	69.78	2	15.38	2	15.38	1	7.69	8	61.54
Champawat	3	8.65	18.1	0	0.00	1	33.33	1	33.33	1	33.33
Pauri Garhwal	1	--	57.68	0	0.00	0	0.00	0	0.00	1	100.00
Total	154	0.82	85.32	55	35.71	42	27.27	17	11.04	40	25.97

The depth to water level maps (August 2016) for Dehradun section in fig 7, Haridwar section is given in Fig. 8 and for Udham Singh Nagar-Nainital-Champawat section is given in Fig. 9.

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for August 2016 is shown in ***Fig. 7****(Dehradun district),* ***Fig 8*** *(Haridwar district)* and ***Fig. 9*** *(Nainital, Udham Singh Nagar and Champawat districts).*

A perusal of **Fig.7** indicates that the shallowest water level (0-5 m) is observed as lenticular patch around the Dandhi and Khandgaon. The water levels in the range of 5-10m are observed as the outlier of the shallowest water level in Rishikesh – Gularghati and Sabhawala – Selaqui – Singhniwala section. The water level in the range of 10-15m is observed in North central and central part of valley; and as linear zone in Kuanawala – Lal Tappar section. More than 50% of the Doon valley shows the deeper water levels (>15m).

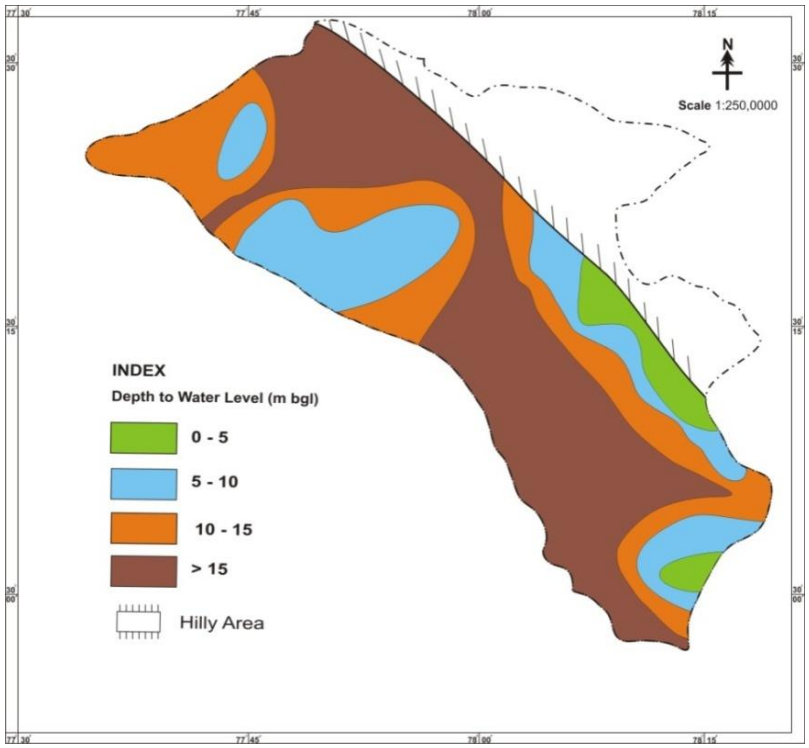


Figure 7 Depth To water Level Map (August 2016), Dehradun District

A perusal of **Fig. 8** indicates that the minimum depth to water level i.e 0-5 m is observed in southern part of the Haridwar district and also as lenticular patches around Sarai - Bahabalpur. The shallowest water levels in the range of 5-10m occurs as linear zone trending from south-west to south-east (Lakhnauta – Kherajat – Roorkee - Sarai section) and also occurs in northern and north wastern part of the Haridwar district. The deeper water levels in the range of 10-15 m are observed mainly in the western and north eastern part of the district i.e Chudiala – Iqbalpur – Bhagwanpur – Bahadrabad section. Whereas, the deepest water levels (>15) occurs as isolated patches around Sikhar and Laldhang (which demarcates the Bhabar zone).

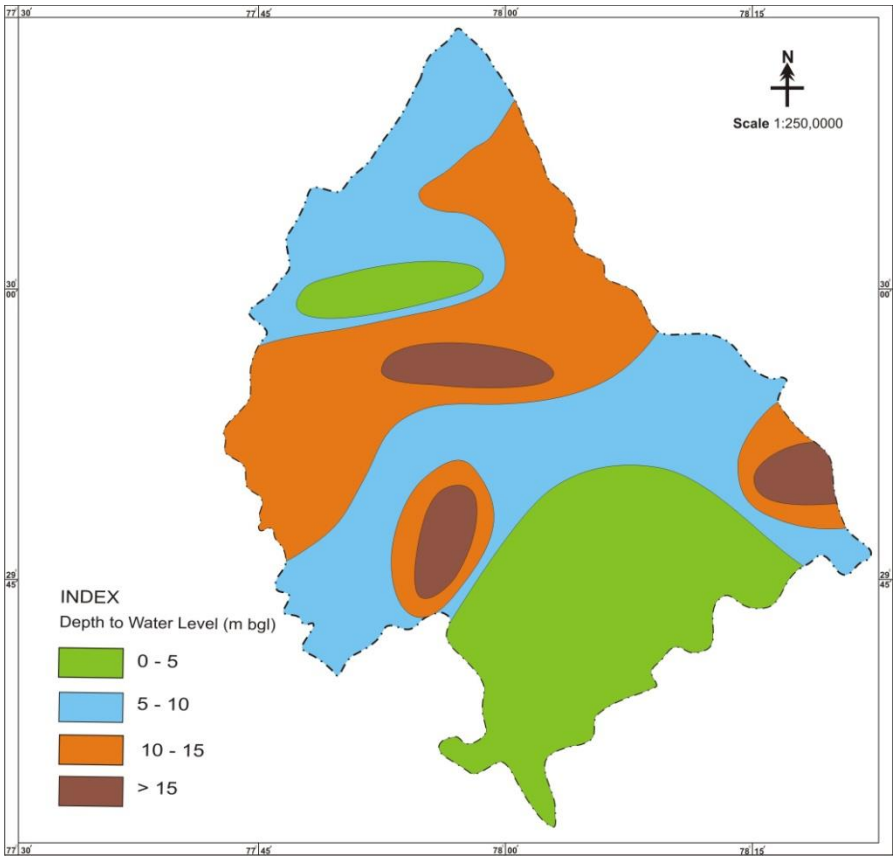


Figure 8 Depth To water Level Map (August 2016), Haridwar District

Interpretation of **Fig. 9** has again revealed that depth to water level generally increases from south to north in Udham Singh Nagar- Nainital- champawat section. The shallowest water level (0-5 m) is observed mainly in the central, southern and south-eastern part of the section (maldhan Colony – Jogipura – Beria Daulat – Pathar Chatta – Gangapur – Nanak Mata). The water level in the range of 5-10m is observed around Kashipur – Barkhare Pande; Bhagwanpur – Begur Mod in Udham Singh Nagar district and Bichayee in Champawat district. This zone is also observed as narrow band running from North Western part of the Nanital district covering central part of district and extending till eastern part of the Champawat district. The water level in the range of 10-15m occurs covering the 5-10 m water levels extending from north western part of the section to eastern part of the section; and also as isolated patch around the Angadpur – Patrampur. The deepest water level (>15 m)is running parallel to the 10-15 m water level zone from north western part of the section continuing upto the Khatbass in the Nanital district; and also as isolated patch around Jaspur in the Udham Singh District.

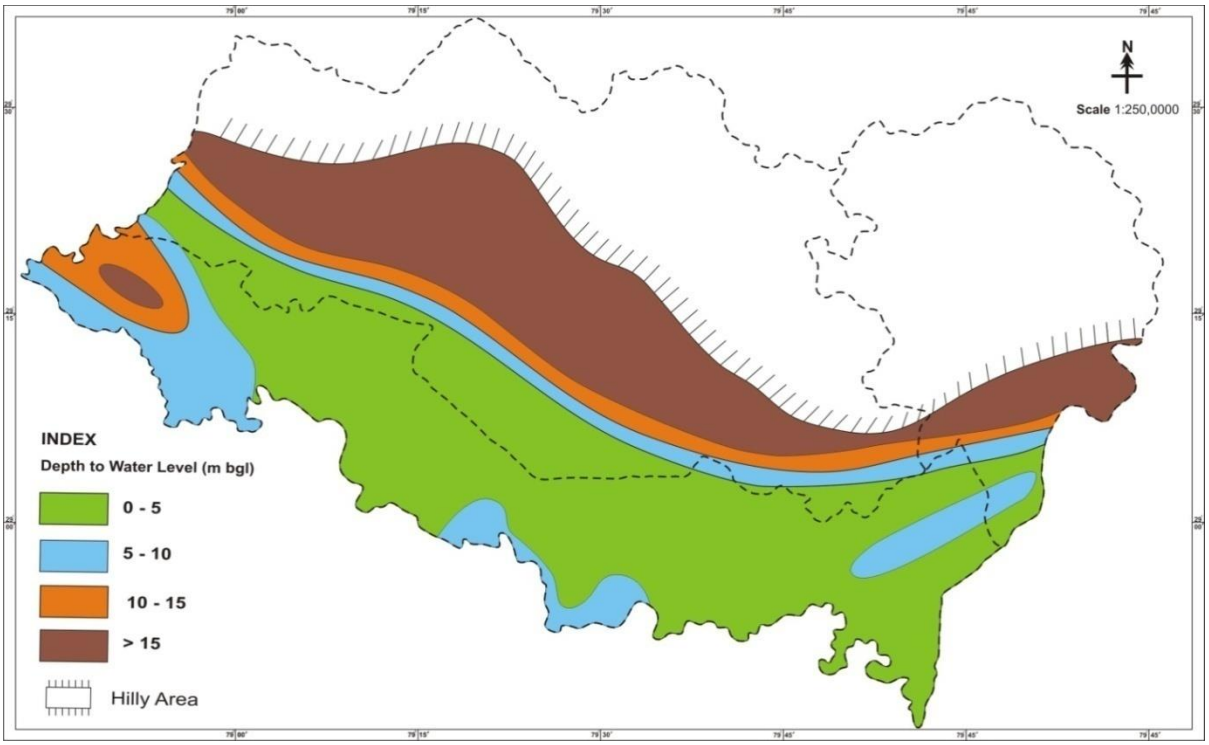


Figure 9 Depth To water Level Map (August 2016), US Nagar – Nainital - Champawat District

5.1.3. November 2016

The depth to water level data is available for 140 Ground Water Monitoring Wells of Uttarakhand during November 2016. The data has been analyzed and shown in ***Table 8***. During this period, the deepest water level of 80.48 m bgl was observed at Dhela Piezometer (Dehradun district) while the shallowest water level of 1.34 m bgl was observed at Sitarganj in Udham Singh Nagar district. The analysis of depth to water level data shows that out of 140 wells, 47 wells (33.57% of total number) have recorded shallowest water level in the depth range of 0–5 m whereas water level in the range of 5-10 m was recorded in 36 monitoring wells (25.71% of the total number). Deeper water level of 10–15 m was observed in 18 wells, which was 12.86% of the total number whereas the deepest water level of >15 m bgl was recorded in 38 wells (27.14% of total wells) in Uttarakhand during November 2016.

Table 8: District wise categorization of depth to water level data, November 2016

District	No. of stations analyzed	Depth to water level (m bgl)		Depth to Water Level (m bgl)							
				0-5		5-10		10-15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	51	3.94	71.7	2	3.92	17	33.33	9	17.65	22	43.14
Haridwar	38	1.57	66.18	13	34.21	13	34.21	7	18.42	5	13.16
U. S. Nagar	37	1.34	13.24	31	83.78	5	13.51	1	2.70	0	0.00
Nainital	11	4	80.48	1	9.09	0	0.00	0	0.00	10	90.91
Champawat	2	9.28	10.63	0	0.00	1	50.00	1	50.00	0	0.00
Pauri Garhwal	1	--	61.37	0	0.00	0	0.00	0	0.00	1	100.00
Total	140	1.34	80.48	47	33.57	36	25.71	18	12.86	38	27.14

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for November 2016 is shown in **Fig. 10** (Dehradun Section), and **Fig. 11** Haridwar Section) and **Fig. 12** (Nainital, Udham Singh Nagar and Champawat Section).

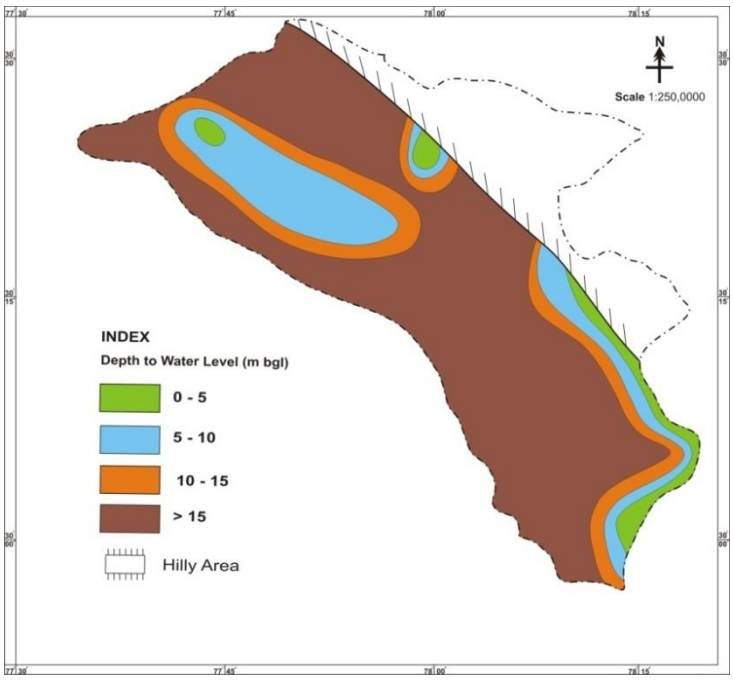


Figure 10 Depth To water Level Map (November 2016), Dehradun District

A perusal of **Fig. 10** reveals that the shallowest water levels (0-5m) are observed as isolated patches around the Dharmawala and as narrow linear zone in Dandhi – Rishikesh – Khangaon area. The water levels in the range of 5-10m are observed as more or less lenticular zone in north central and central part of Doon valley covering the Herbertpur-Redarpur- Sabhawala-Nanda Ki Chown section) and as outlier to the 0-5m water level zones. The water levels in the range of 10-15m are observed as a

narrow concentric zone surrounding the 5-10m water level zone in north central and central part of Doon valley and as isolated patch around the Gularghat. Majority of the Doon Valley shows the water deeper than 15 m.

A perusal of **Fig. 11** reveals that the shallowest water level (0-5 m) occurs mostly in the Southern part of Haridwar District and as isolated patch around Bahabalpur - Rathura. The water levels in the range of 5-10m are observed in the Northern part of the district and also as broad continuous band extending from south western part covering central part of the district and then tapers to the south eastern part of the Haridwar District. The water levels in the range of 10-15 m are observed in between 5-10m water level zone and as elliptical patch around the Nizampur - Landhaura. The deeper water level (>15m)are observed as inlier in the 10-15m water level zone in southeastern part of the district; as isolated patche around Laldhang.

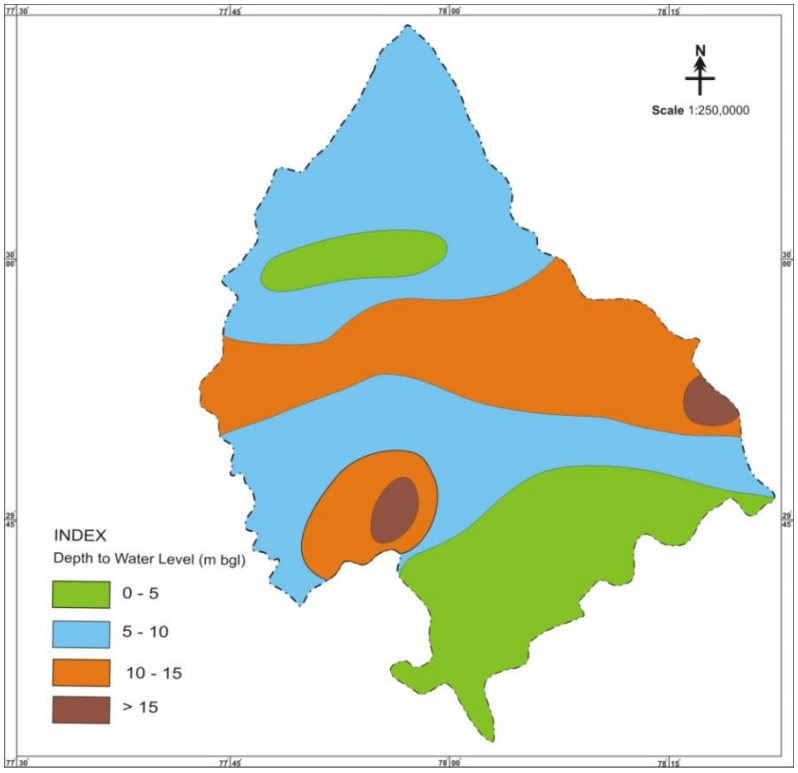


Figure 11 Depth To water Level Map (November 2016), Haridwar District

Interpretation of **Fig. 12** has again revealed that depth to water level generally

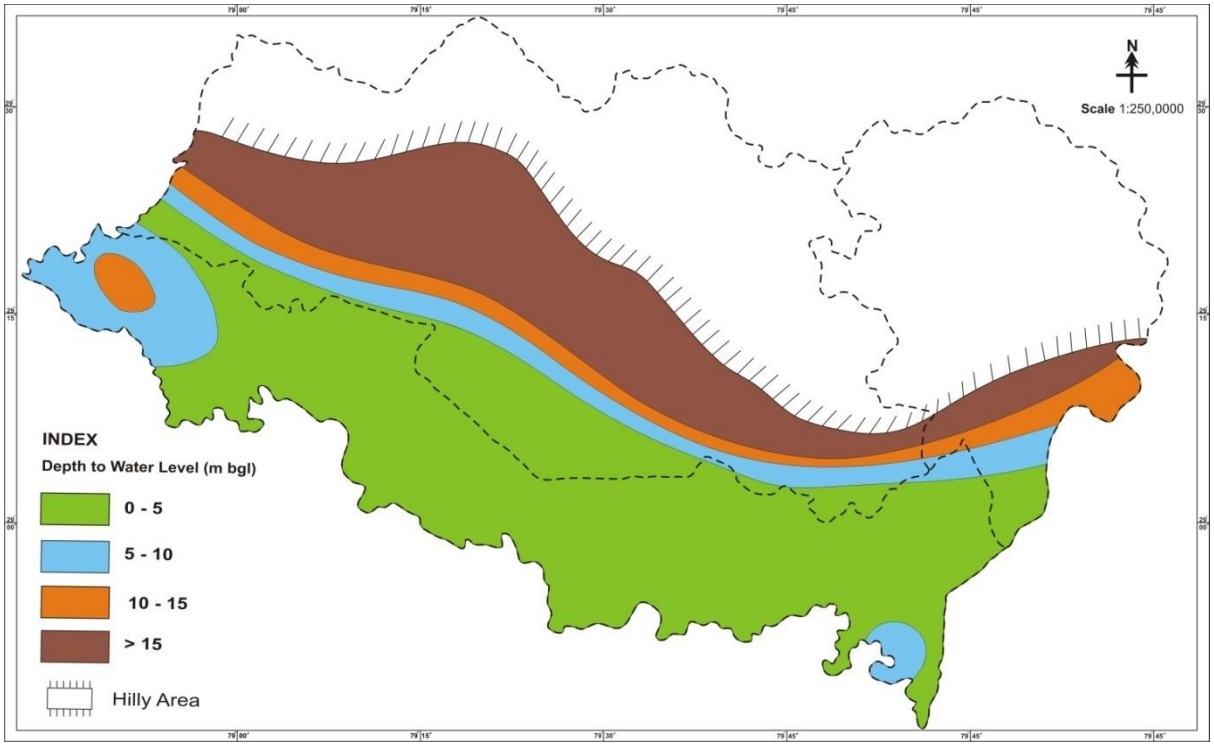


Figure 12 Depth To water Level Map (November 2016), US Nagar – Nainital - Champawat District

increases from south to north in Udham Singh Nagar- Nainital- champawat section. The shallowest water level (0-5 m) is observed mainly in the central, southern and south-eastern part of the section (maldhan Colony – Jogipura – Beria Daulat – Pathar Chatta – Gangapur – Nanak Mata). The water level in the range of 5-10m is observed around Bharatpur – Patrampur – Missarwala and Majhola as isolated patch in Udham Singh Nagar District. This zone is also observed as narrow band running from North Western part of the Nanital district covering central part of district and extending till eastern part of the Champawat district. The water level in the range of 10-15m occurs covering the 5-10 m water levels extending from north western part of the section to eastern part of the section; and also as isolated patch around the Jaspur. The deepest water level (>15 m)is running parallel to the 10-15 m water level zone from north western part of the section continuing upto the Khatbass in the Nanital district. The deepest water levels (>15 m) are observed mostly in northern part of Bhabhar Belt.

5.1.4 January 2017

The depth to water level data was analysed for 156 Ground Water Monitoring Wells in Uttarakhand during January 2017 and is given in ***Table 9.*** Analysis of depth to water level data given in the table indicates that the deepest water level was 85.65 m bgl in a piezometer at Ladpur, Dehradun district whereas the shallowest water level was 1.28 m bgl at Jharkhandi in Udham Singh Nagar district. The shallowest depth to water level of 0–5 m bgl was recorded by 53 monitoring wells, which was 33.97 % of the total number of wells. Water level in the range of 5-10 m bgl was also shown by 33 wells (21.15% of total number of wells), whereas deeper water level of 10–15 m bgl was recorded by 29 monitoring wells, which was 18.59% of the total number of wells. The deepest water level of >15 m bgl was shown by 41 monitoring wells, which was 2628% of the total number of wells in Uttarakhand monitored in January 2017.

Table 9: District wise categorization of depth to water level data, January 2017

District	No. of stations analyzed	Depth to water level (m bgl)		Depth to Water Level (m bgl)							
				0-5		5-10		10-15		>15	
		Min	Max	No.	%	No.	%	No.	%	No.	%
Dehradun	54	2.1	85.65	1	1.85	13	24.07	17	31.48	23	42.59
Haridwar	39	1.45	61.57	13	33.33	10	25.64	9	23.08	7	17.95
U. S. Nagar	45	1.28	13.26	36	80.00	8	17.78	1	2.22	0	0.00
Nainital	13	4	65.43	2	15.38	1	7.69	1	7.69	9	69.23
Champawat	4	4.38	39.49	1	25.00	1	25.00	1	25.00	1	25.00
Pauri Garhwal	1	--	57.2	0	0.00	0	0.00	0	0.00	1	100.00
Total	156	1.28	85.65	53	33.97	33	21.15	29	18.59	41	26.28

The depth to water level map of the plain areas and parts of hilly areas of Uttarakhand for ***January 2017*** is shown in ***Fig. 13*** *(Dehradun Section),* ***Fig. 14*** *(Haridwar Section)* and ***Fig. 15*** *(Nainital, Udham Singh Nagar and Champawat Section).*

A perusal of **Fig. 13** reveals that the shallowest water levels (0-5 m) are observed in the isolated patches around Dandhi. Water levels in the range of 5-10 m are observed in narrow zones in Rampur – Redarpur – Dharmawala - Selaqui section and as isolated patch around Khandgaon. The water level in the range of 10-15 m is observed as outlier to the 5-10 m water level zone in central part of Doon valley. This zonwe is also dominant in Southern part of Doon Gravels around Lal tappar- Motichur - Rhishikesh Section. More than 70 % of the Doon valley shows deeper water levels (>15m).

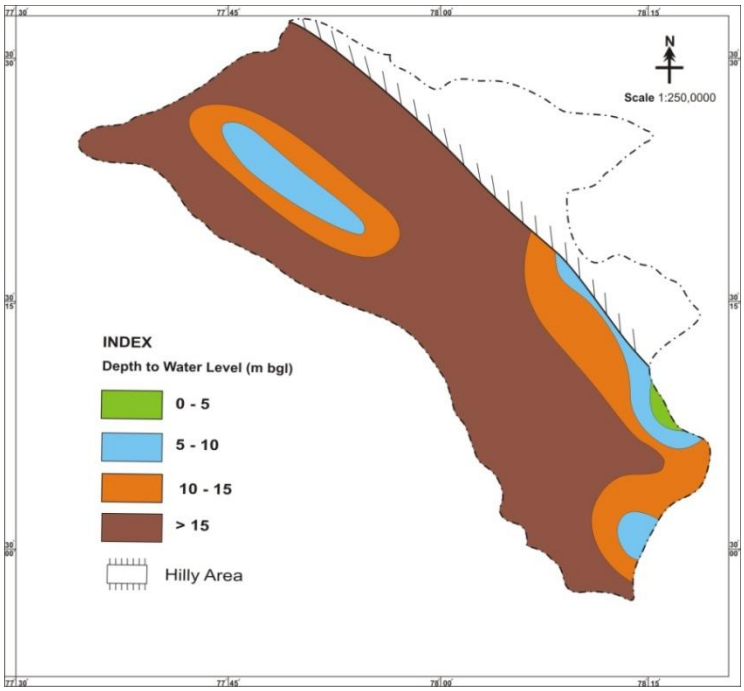


Figure 13 Depth To water Level Map (January 2017), Dehradun District

A study of ***Fig. 14*** that the shallowest water levels in the range of 0-5m occurs dominantly covering the southern Part of Haridwar District (Bhikkampur –Shapur Shitlakhera – Dallawala section) and as isolated patch around Bahabalpur. The water levels in the range of 5-10m observed around the Buggawala – Bandarjud section in the north and also as broad continuous band extending from south western part covering central part of the district and then tapers to the south eastern part of the Haridwar District. The water levels in the range of 10-15 m are observed around Iqbalpur – Bhagwanpur – Bahadrabad – Sarai in the central part of the distric and as outlier of > 15m water level zone around Manglaur. Deeper water level (>15m) occurs as isolated patches around Chudiala, Sikhar and Laldhang.

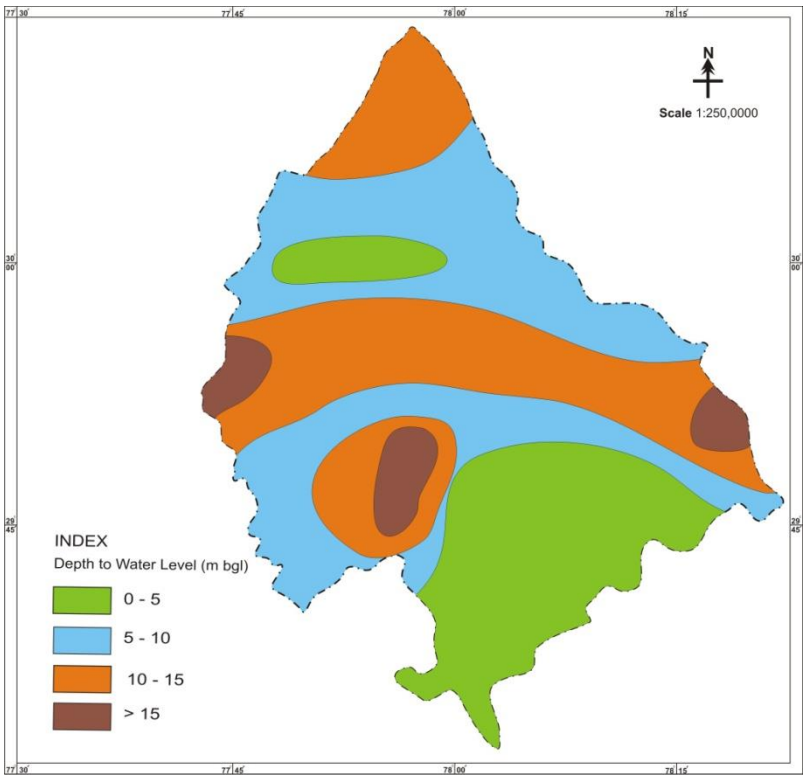


Figure 14 Depth To water Level Map (January 2017), Haridwar District

Interpretation of **Fig. 15** has again revealed that depth to water level generally increases from south to north in Udham Singh Nagar- Nainital- champawat section. The shallowest water level (0-5 m) is observed mainly in the central, southern and south-eastern part of the section (Maldhan Colony – Jogipura – Beria Daulat – Pathar Chatta – Gangapur – Nanak Mata). The water level in the range of 5-10m is observed around Kashipur – Patrampur - Angadpur – Missarwala; and as isolated patch around Chakarpur & Kichha in Udham Singh Nagar District. This zone is also observed as narrow band running from North Western part of the Nanital district covering central part of district and extending till eastern part of the Champawat district. The water level in the range of 10-15m occurs covering the 5-10 m water levels extending from north western part of the section to eastern part of the section; and also as isolated patch around the Jaspur – Bharatpur in Udham Singh Nagar district. The deepest water levels (>15 m) are observed mostly in northern part of Bhabhar Belt. The deepest water level (>15 m) is running parallel to the 10-15 m water level zone from north western part of the section continuing upto the Bastia in the Nanital district.

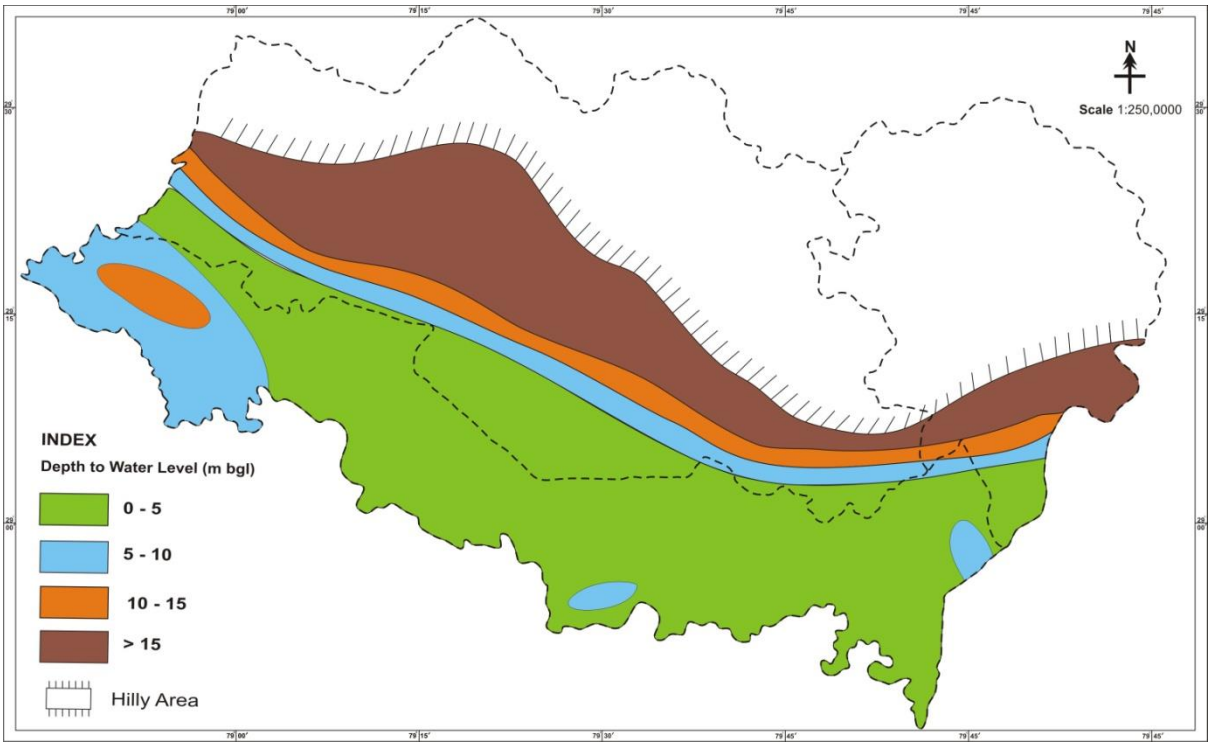


Figure 15 Depth To water Level Map (January 2017), US Nagar – Nainital - Champawat District

5.2 DISCHARGE OF SPRINGS

The discharge data of thirty-Eight cold-water springs in Dehradun, Nainital, Uttarkashi and Almora districts for the months of May, August, November 2016 and January 2017 is given in ***Table 10.*** A study of the table shows that spring discharge is lowest in pre-monsoon (May) whereas during post-monsoon (August), the discharge increased significantly. This indicates that rainfall is the principal contributing factor for variation in spring discharge.

A perusal of ***Table 10*** indicates that discharge of the cold-water springs during the period May 2016-January 2017 varies from a minimum measurable discharge of 1.27 LPM at Someshwar in January 2017 to a maximum of 235 LPM at Sipahidhara (August 2016). Discharge of springs varies within wide limits during the intervening period.

In Dehradun district, spring discharge varies between 2.07 LPM at Soda Sarauli in May 2016 and 25 LPM at Bhatta in May 2016. In Nainital district, spring discharge varies from a minimum of 0.6 LPM at Salari (May 2016) to a maximum of 235 LPM at Sipahidhara (August 2016). In Almora district, the spring discharge was found to be varying from a minimum of 1.15 LPM at Palna in May 2016 to a maximum of 142.86 LPM at Peepal Dhar in November 2016. In Uttarkashi district, spring discharge was varying from 2.85 LPM at Dharasau in August 2016 to a maximum of 97.5 LPM in Ganganani in January 2017.

Table 10: Discharge of Springs in May, August, November 2016 and January 2017

SL. No.	Location	May-16	Aug-16	Nov-16	Jan-17
DEHRADUN DISTRICT					
1	Bhatta	25 lpm	7.20 lpm	3.09 lpm	3 lpm
2	Khandoli	15 lpm	14.66 lpm	7.2 lpm	20 lpm
3	Soda Sarauli	2.07 lpm	20 lpm	9.09 lpm	NA
UTTARKASHI DISTRICT					
4	Dharasu	5.71 lpm	2.85 lpm	0.83 lpm	12.5 lpm
5	Nagal	7.50 lpm	18.47 lpm	7.24 lpm	30.0 lpm
6	Ratodi Sar	6.0 lpm	26.35 lpm	11.29 lpm	7.5 lpm
7	Ganganani	NA	34.13 lpm	NA	97.5 lpm
NAINITAL DISTRICT					
8	Dogaon	NA	50 lpm	23.68 lpm	7.03 lpm
9	Sipahidhara	75 lpm	235 lpm	186.53 lpm	19.69 lpm
10	Garampani	40 lpm	20 lpm	14.29 lpm	16.67 lpm
11	Salari	0.6 lpm	60 lpm	4.69 lpm	4.04 lpm
12	Ranibagh	8.57 lpm	60 lpm	29.65 lpm	7.90 lpm
13	Jeolykot	4.28 lpm	37.5 lpm	20 lpm	15.62 lpm
15	Kudagath	4.28 lpm	42.86 lpm	2.9 lpm	2.78 lpm

ALMORA DISTRICT					
16	Patali Talla	30 lpm	12 lpm	37.5 lpm	9.32 lpm
17	Patali Malla	16.66 lpm	15 lpm	9.68 lpm	6.10 lpm
18	Katarmal	15.00 lpm	60.00 lpm	20 lpm	14.81 lpm
19	Dhara Naula	3.75 lpm	4.29 lpm	1.43 lpm	8.80 lpm
20	Palna	1.15 lpm	10 lpm	3 lpm	2.11 lpm
21	Chinoda	1.30 lpm	3.53 lpm	2.22 lpm	1.58 lpm
22	Guruda	1.76 lpm	5 lpm	12.03 lpm	5.55 lpm
23	Dhansari	37.5 lpm	42.85 lpm	124.28 lpm	15.46 lpm
24	Someshwar	8.57 lpm	3.53 lpm	1.41 lpm	1.27 lpm
25	Bhoolgaon	30 lpm	NA	41.74 lpm	6.63 lpm
26	Deepakot	6.60 lpm	15 lpm	12.15 lpm	10.83 lpm
27	Ramgath	3.52 lpm	6 lpm	NA	3.43 lpm
28	Bhagtola	1.76 lpm	20 lpm	2.5 lpm	1.80 lpm
29	Itola	2.14 lpm	6.67 lpm	4 lpm	3.02 lpm
30	Potarsain	NA	30 lpm	NA	NA
31	Chhani Bartola	6 lpm	30 lpm	11.54 lpm	8.55 lpm
32	Lodh SP	3.3 lpm	12 lpm	3.9 lpm	2.05 lpm
33	Peepal Dhar	30 lpm	43.64 lpm	142.86 lpm	NA
34	Dhalnagaon	7.5 lpm	6 lpm	9.38 lpm	7.58 lpm
35	Semalkhet	1.76 lpm	20 lpm	5.16 lpm	3.05 lpm
36	Naulla	7.5 lpm	7.5 lpm	11.76 lpm	5.33 lpm
37	Baniya Diggi	3.75 lpm	5 lpm	4.41 lpm	1.76 lpm
38	Jholi	NA	5 lpm	15 lpm	13.64 lpm

NA: Not Available

5.3 LONG TERM (DECADAL) DEPTH TO WATER LEVEL

The available long-term data of ground water levels in some of the Ground Water Monitoring Wells of the state was analyzed to have an idea of the decadal (long-term) water level data and decadal versus current depth to water level fluctuations. The average value of depth to water level for selected Ground Water Monitoring Wells (based on availability of long-term water level data) was calculated for the past ten years (May, August and November for the period from 2006 to 2016 and January for the period from 2007 to 2017). The average depth to water level data available for maximum 78 Ground Water Monitoring Wells is given in ***Table 11.***

Table 11: Long-term (Decadal) Depth to Water Level Data, Uttarakhand State

Sr. No.	Location	Depth to Water Level (m bgl)			
		Avg. May	Avg. August	Avg. November	Avg. January
		2006-2015			2007-2016
Dehradun District					
1	**Lal Tappar**	19.28	13.53	12.18	13.10
2	**Bhaniawala**	NA	18.45	21.74	25.01
3	**Balliwala**	54.92	54.18	52.35	51.82
4	**Nanurkhera**	70.52	69.72	60.62	61.77
5	**Tarla Nagal**	75.66	65.86	67.27	67.87
6	**Harbanswala**	52.33	48.61	40.74	NA
7	**Majra**	23.06	21.20	20.19	NA
8	**Kanwali**	14.84	9.13	13.22	14.73
9	**Singhniwala**	9.62	6.48	9.06	9.44
10	**Ramgarh**	7.44	4.27	6.60	6.32
11	**Jhajra**	12.51	5.88	6.98	8.63
12	**Nanda ki Chowki**	14.48	7.31	8.96	9.82
13	**Selakui**		6.84	8.52	9.07
14	**Sabhawala**	9.25	5.49	7.84	8.19
15	**Rampura**	13.93	7.03	11.65	12.31
16	**Shankarpur**	23.20	15.88	17.88	19.27
17	**Redapur**	8.93	5.83	4.30	5.99
18	**Judli**	12.54	10.93	12.04	13.34
19	**Herbertpur**	10.06	5.30	8.35	9.54
District Haridwar					
20	**Shahidwala Grant**	12.69	10.96	11.33	11.31
21	**Sahidwala Grant**	11.87		9.11	8.86
22	**Bahabalpur**	3.12	2.60	3.03	3.23

23	**Bhagwanpur**	20.86	16.45	18.09	14.84
24	**Chudiala**	21.13	NA	18.92	18.58
25	**Iqbalpur**	16.96	13.03	15.45	14.75
26	**Bandarjud**	10.87	8.28	7.84	8.40
27	**Rathora**	5.56	4.27	4.13	5.30
28	**Bahadrabad**	8.68	12.54	12.86	11.71
29	**Sarai**	10.95	9.06	10.44	11.87
30	**Dhanpura**	8.86	4.70	10.05	5.93
31	**Shahpur Shitlakhera**	4.67	2.77	3.38	3.79
32	**Laldhang**	61.01	NA	54.06	56.65
33	**Imlikhera**	17.71	11.70	9.89	13.44
34	**Roorkee**	7.46	5.49	6.33	6.08
35	**Jhabreda**	10.32	7.51	9.49	8.50
36	**Landhaura**	18.01	15.83	17.19	17.89
37	**Lakhnauta**	5.22	4.90	4.59	6.53
38	**Gurukul Narsen**	5.60	3.36	5.36	5.58
39	**Hussainpur**	3.97	1.49	2.60	2.46
40	**Bhikkampur**	4.58	2.35	3.18	4.72
41	**Govardhanpur**	4.43	2.28	**3.23**	NA
42	**Dallawala**	2.10		1.66	1.99
43	**Khanpur**	4.11	1.41	3.17	2.17
District Udham Singh Nagar					
44	**Jaspur**	8.68	9.91	8.31	10.19
45	**Patrampur**	10.31	7.88	6.99	7.20
46	**Angadpur**	6.41	4.18	NA	4.28
47	**Barkhare Pande**	8.11	5.16	NA	5.96
48	**Sultanpur Patti**	3.33	0.60	0.48	1.50
49	**Kashipur**	6.46	3.35	4.40	4.27
50	**Bharatpur**	8.21	6.54	5.96	5.63
51	**Dhanauri Patti**	4.63	2.44	2.59	2.92
52	**Bazpur**	2.63	0.63	1.51	1.79
53	**Jogipura**	7.27	4.09	4.24	4.80
54	**Banna Khera**	5.11	3.40	3.56	3.83
55	**Jhagarpuri**	2.75	1.22	1.84	2.24
56	**Mahabir Nagar**	2.70	1.24	2.03	2.64
57	**Beria Daulat**	3.80	1.98	2.67	3.02
58	**Bhagwanpur**	6.28	4.14	NA	3.91
59	**Bara**	2.48	1.04	1.76	2.02
60	**Kichha**	8.02	5.80	NA	6.85

61	**Kamaria Pakki**	7.25	4.12	3.43	5.06
62	**Gangapur**	3.22	2.75	2.39	2.65
63	**Shantipuri**	2.37	0.98	1.59	1.72
64	**Patthar Chatta**	2.90	1.98	NA	2.64
65	**Sitarganj**	3.69	1.39	1.94	1.86
66	**Nanak Mata**	5.38	2.41	3.13	3.77
67	**Kanchanpur (Majhola) HP**	4.74	3.13	3.63	4.46
68	**Khatima**	3.34	1.25	1.64	2.54
69	**Chakarpur**	5.82	4.60	4.75	5.57
District Nainital					
70	**Peeru Madara**	24.28	21.84	17.98	19.81
71	**Dhela**	63.69	65.52	64.73	57.81
72	**Garjiya**	4.44	2.92	4.29	4.67
73	**Dohniya**	70.24	67.15	61.87	59.38
74	**Khaat Baans**	36.34	24.27	27.92	26.94
75	**Kaladungi**	26.78	26.72	26.77	27.86
76	**Kathgodam**	20.62	15.19	17.80	20.01
District Champawat					
77	**Banbasa**	6.98	NA	NA	5.17
78	**Bastia**	31.44	25.22	NA	29.77

NA: Not Available

A perusal of the long-term (decadal) depth to water level data given in ***Table11*** indicates that the depth to water level varies widely. The minimum long-term water level is 0.48 m at Sultanpur patti in Udham Singh Nagar District in November whereas the maximum was 75.66 m bgl at Tarla Nagal in Dehradun district in May.

The table also shows that for Dehradun district, the minimum long-term water level is 4.27 m bgl at Ramgarh in August whereas the maximum is 75.66 m bgl at Tarla Nagal in May. In Haridwar district, decadal water level is varying from 1.41 m bgl at Khanpur in August to the maximum of 61.01 m bgl at laldhang in May. In Udham Singh Nagar district, the long-term depth to water level is varying from 0.48 m bgl at Sultanpur Patti in November to 10.31 m bgl at Patrampur hand pump in May viz. in the pre-monsoon period. The decadal water level in Nainital district was varying from 2.92 m bgl at Garjia in August to a maximum of 70.24 m bgl at Dhoniya hand pump in May viz. in the pre-monsoon period. Long-term depth to water level in Champawat district was ranging from 5.17 m bgl at Banbasa Handpump in January to 31.44 m bgl at Bastia hand pump in May viz. during pre-monsoon period.

5.4 WATER LEVEL FLUCTUATION

The changes in ground water level in response to recharge and ground water withdrawal are important aspects for study of the overall hydrogeological scenario of an area. The water level fluctuation is calculated in each case under the following three categories.

- Changes in water level during each period of observation with respect to average water level for the last ten years for that period.
- Changes in water level during each season/period with respect to observed data of pre-monsoon water level during the same year.
- Changes in water level during each season/period with respect to water levels observed in previous year of the same period.

Tables and maps, which show the long-term (decadal), yearly and seasonal water level fluctuations, were prepared for the monitoring wells of Dehradun, Haridwar, Udham Singh Nagar, Nainital and Champawat district. The analysis of water level fluctuation data and conclusion drawn from it are discussed below.

5.4.1 DECADAL (LONG-TERM) WATER LEVEL FLUCTUATION

5.4.1.1 Water Level Fluctuation (May 2006-2015 versus May 2016)

The analysis of decadal depth to water level data for 78 ground water monitoring wells is given in ***Table 12***. A perusal of the table indicates that the minimum long-term rise in the range of 0-2 m is observed in 25 monitoring wells (32.1 % of the total number) whereas higher rise in the range of 2-4 m is observed in 6 wells (7.69 % of total). The 5 no of well (6.41%) recorded the decadal rise in water level (>4 m). The lowest long-term decline in the range of 0-2 m is recorded in 26 wells, which is 33.3 % of the total number. Higher long-term decline in the range of 2-4 m is recorded in 8 wells, which is 10.3 % and the highest decline of >4 m is recorded in 6 wells, which is 7.69 % of the total number. Analysis of the decadal data also shows that the lowest decadal rise is 0.09 m at Khatima in Udham Singh Nagar district while the highest rise is 32.96 m at Dhoniya in Nainital district. The lowest long-term decline in water level is 0.05 m at Chakarpur in Udham Singh Nagar district while the highest is 9.52 m at Harbanswala in Dehradun district.

The decadal water level fluctuation map for average (May 2006-2015) versus May 2016 is shown in ***Fig.16*** *(Dehradun Section),* ***Fig.17*** *(Haridwar section)* and ***Fig. 18*** *(Nainital-Udham Singh Nagar-Champawat section)*.

A study of **Fig. 16** reveals that the minimum rise of 0-2 m is observed in narrow patches around Nanda Ki Chowki and Herbertpur – Rampur area. Higher decadal rise of 2-4 m is observed around Lal Tappar only. The highest decadal rise of >4 m is not observed in Dehradun district according to the available data. Decadal decline in water level in the range of 0-2 m is observed in >70% of the Dehradun district. The decadal decline in the range of 2-4 m is observed as semicircular zone in and around Jhajra. The decline in water levels >4m is observed around Harbanswala – Balliwala section.

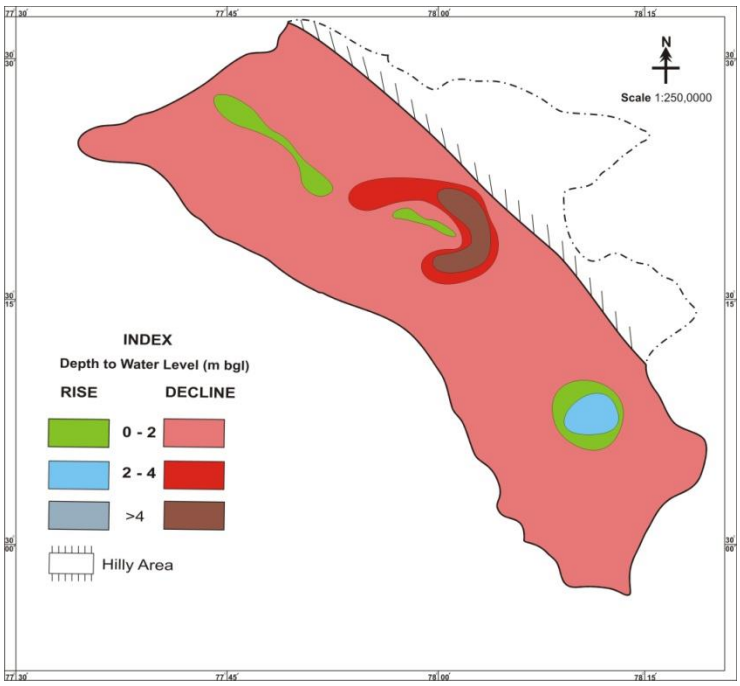


Figure 15 Decadal Water Level Fluctuation Map (May 2006-2015 vs 2016), Dehradun District

A study of **Fig. 17** reveals that the minimum rise of 0-2 m is observed around Bhikampur – Dallawala - Goverdhanpur area in southern part of the district. Higher decadal rise of 2-4 m is observed around the Bandarjud – Rathura - Sahidwala Grant area and the highest decadal rise of >4 m is observed around Chudiala - Bhagwanpur. Decadal decline in water level in the range of 0-2 m is observed in more than 50% of the Haridwar District. Decline in the range of 2-4 m is observed around Gurkul Narsen and Sarai; whereas the decline in water levels >4m is observed around Kanpur and Laldhang only.

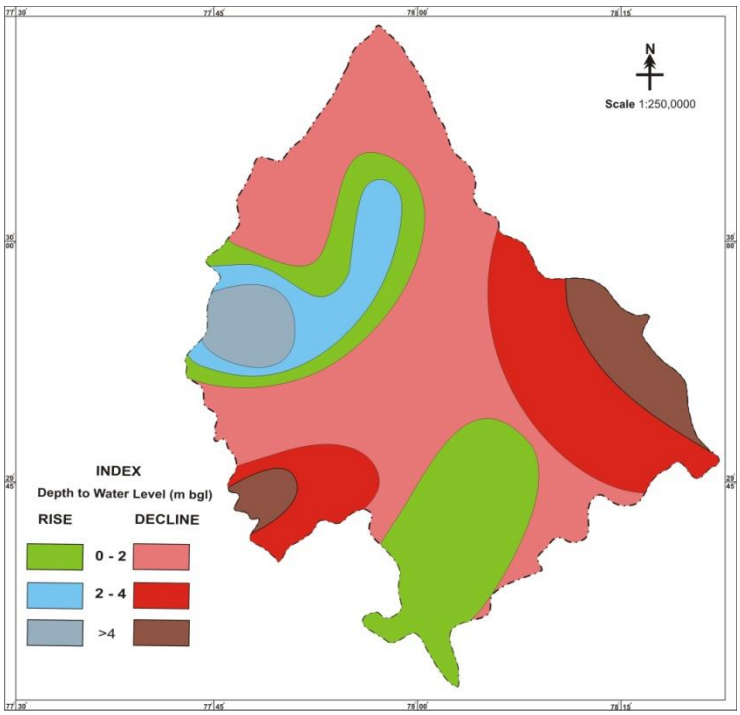


Figure 16 Decadal Water Level Fluctuation Map (May 2006-2015 vs 2016), Haridwar District

Interpretaton of **Fig. 18** has shown that decadal rise of 0-2 m is observed around Angadpurn - Paytrampur, Sultanpur patti- Sitarganj- Bara-Khatima-Nanak Mata section of Udham Singh Nagar district (in the Tarai zone), in Kathgodham in Nainital district falling in the Bhabar zone and around Bastia in Champawat district. Rise of 2-4 m is observed as outlier to the >4 m water level zone. Highest decadal rise of >4 m is observed in khatbass and Dhoniya in Nainital District. Decadal decline in water level in the range of 0-2 m is observed in majority of the areas in the entire Udham Singh Nagar-Nainital-Champawat section. Decadal decline in the range of 2-4 m is observed around Dhela, and Peeru Madara in Nainital district and Banbasa in Champawat District. Highest decadal decline of >4 m is observed around Jaspur (Udham Singh Nagar); Kaladhungi, in Nanital districts).

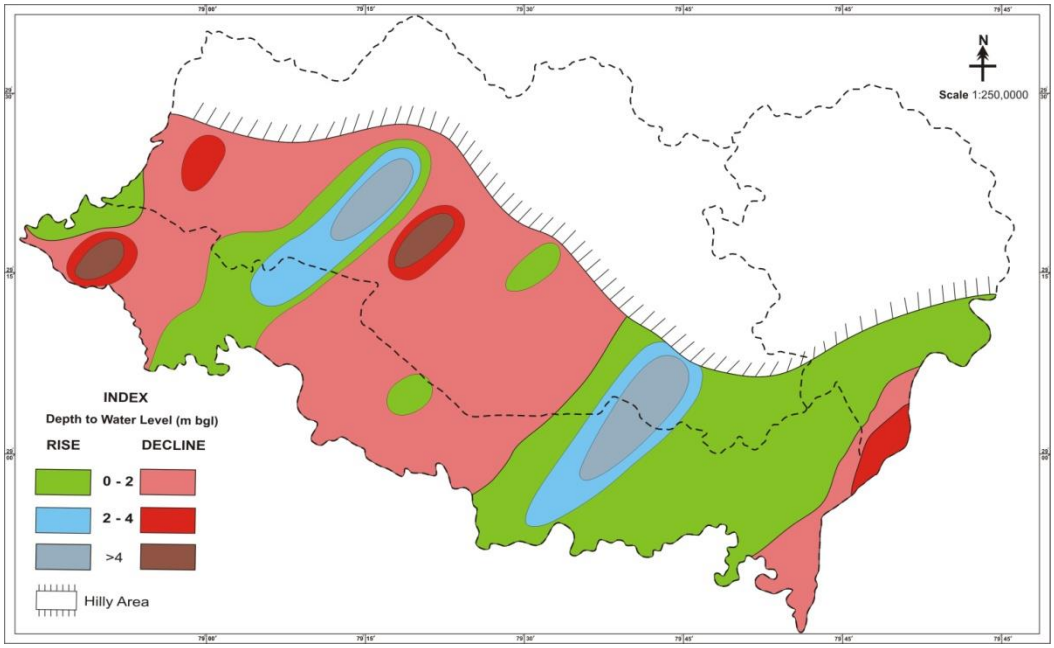


Figure 17 Decadal Water Level Fluctuation Map (May 2006-2015 vs 2016), US Nagar – Nainital - Champawat District

Table 12. Decadal Water Level Fluctuation (May 2006 –May 2015 Versus May 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.45	2.08	0.15	9.52	4	21.1	1	5.26	0	0	8	42.1	2	10.5	2	10.5
Haridwar	24	0.2	9.89	0.11	8.21	6	25	3	12.5	3	12.5	7	29.2	3	12.5	2	8.33
U. S. Nagar	26	0.09	3.15	0.05	7.15	13	50	2	7.69	0	0	10	38.5	0	0	1	3.85
Nainital	7	1.28	32.96	0.52	4.97	1	14.3	0	0	2	28.6	1	14.3	2	28.6	1	14.3
Champawat	2	--	1	--	3.65	1	50	0	0	0	0	0	0	1	50	0	0
Total	**78**	**0.09**	**32.96**	**0.05**	**9.52**	**25**	32.1	**6**	7.69	**5**	6.41	**26**	33.3	**8**	10.3	**6**	7.69

5.4.1.2 Water Level Fluctuation (August 2006-2015 versus August 2016)

Long-term water level data for 73 monitoring wells is analyzed and is shown in ***Table 13***. A perusal of the data shows that the minimum decadal rise is 0.11 m at Sitarganj Dug well in Udham Singh Nagar district whereas the maximum decadal rise is 10.16 m at Nanukhera Hand pump in Dehradun district. The minimum long-term decline in water level is 0.02 m at Rathura Dug well in Haridwar district; whereas the maximum decadal decline of 8.94 m is recorded at Angadpur Hand Pump in Udham Singh Nagar district.

A perusal of **Table 13** indicates that the minimum long-term rise in the range of 0-2 m is observed in 17 monitoring wells (23.3% of the total number), whereas higher rise in the range of 2-4 m is observed in 2 wells (2.74% of total) and the highest rise of >4 m is observed in 5 monitoring wells (6.85% of total). The lowest long-term decline of water level in the range of 0-2 m is recorded in 31 monitoring wells, which is 42.5 % of the total number. Higher long-term decline in the range of 2-4 m is recorded by 9 wells (12.3 % of total) whereas the highest decline of >4 m is observed in 9 monitoring wells, which is 12.3% of the total number of wells.

The decadal water level fluctuation map for average (August 2006-2015) versus August 2016 is shown in ***Fig.19*** *(Dehradun, Section),* ***Fig.20*** *(Haridwar section)* and ***Fig. 21*** *(Nainital -Udham Singh Nagar-Champawat section).*

Visual interpretation of **Fig. 19** has shown that minimum decadal rise of 0-2 m is found in the isolated patch around Sabhawala and also as outlier to the 2 – 4m water level zone in eastern part of the district. Decadal rise of 2-4 m is observed around Bhaniawala and >4 m is observed around Nanukhera in Doon valley. The long-term decline of 0-2 m is observed in more than 70% of the Doon Valley. Higher decline of 2-4 m is observed as linear patche around Herbertpur-Redarpur section and as isolated patch around Laltappar. Long term deeper water level decline (>4m) is observed around the Shankarpur and Balliwala-Harbanswala section.

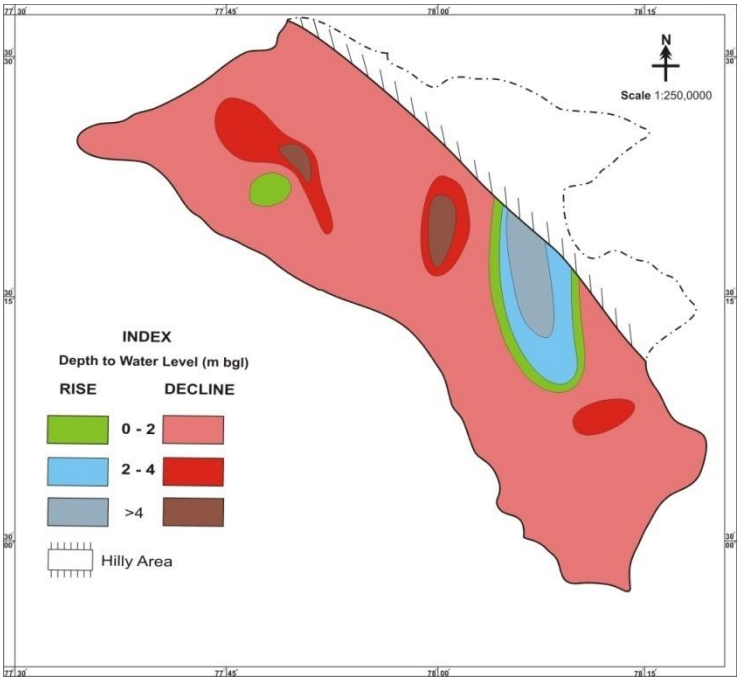


Figure 19 Decadal Water Level Fluctuation Map (August 2006-2015 vs 2016), Dehradun District

Visual interpretation of **Fig. 20** has shown that minimum decadal rise of 0-2 m is observed around the Sahidwala Grant – Bandarjud – Bhagwanpur and as elliptical patch around Bhikampur – Husainpur in southern part of the district. No monitoring wells shown the decadal rise in the range of 2-4m and >4m in Haridwar District. The minimum long-term decline of 0-2 m is observed in more than 70% of the Haridwar District. Higher decline of 2-4 m is observed around the Jhabrea. Long term deeper water level decline (>4m) is observed around the Baharabad – Sahidwala grant.

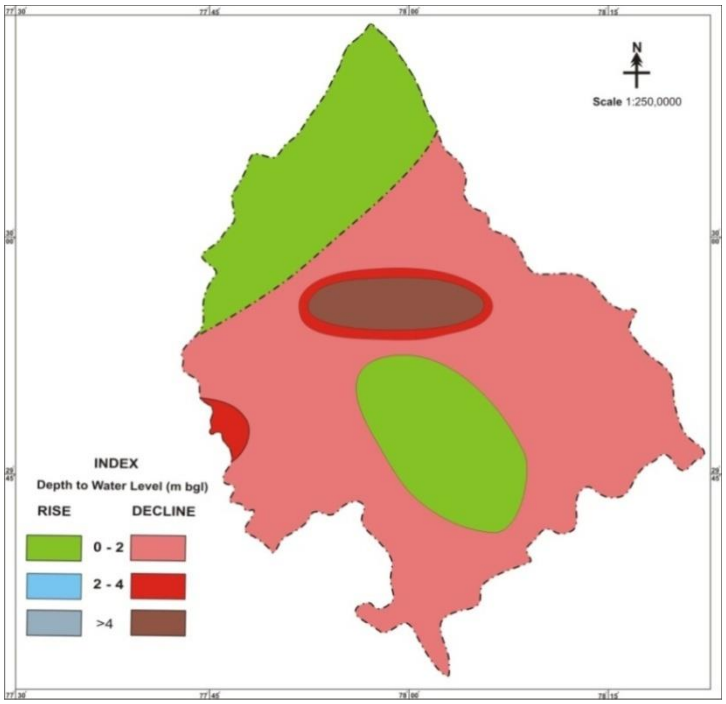


Figure 20 Decadal Water Level Fluctuation Map (August 2006-2015 vs 2016), Haridwar District

Visual interpretation of **Fig. 21** reveals that minimum decadal rise of 0-2 m is seen dominantly in south eastern part of section and also as isolated patches around Dhoniya in Nanital District and Jogipura (Udham Singh Nagar district). Higher decadal rise of 2-4 m is seen only in the isolated patch at Kamaria pakki in Udham Singh Nagar District and as outlier to the >4m water level zone. The highest decadal rise of >4 m is observed around Khatbass – Khatgodam in Nanital district and Bastia in Champawat District. The lowest decadal decline of 0-2 m is observed in major part of Tarai zone in Udham Singh Nagar district and the same situation is also seen in

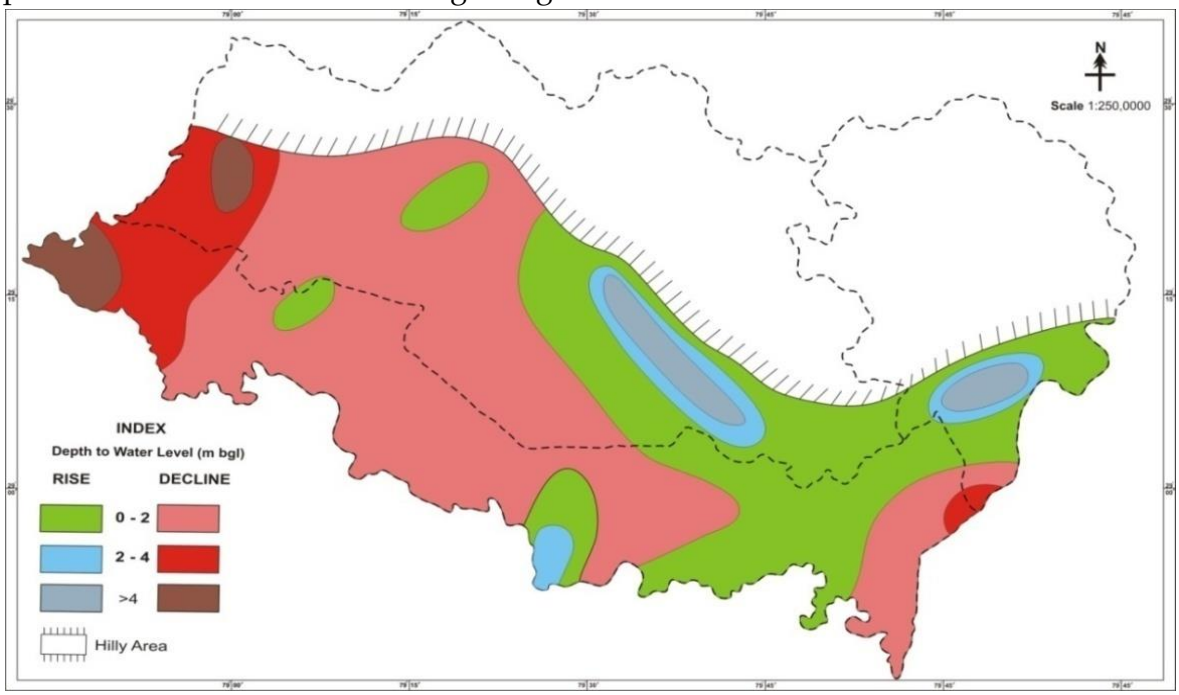


Figure 21 Decadal Water Level Fluctuation Map (August 2006-2015 vs 2016), US Nagar – Nainital - Champawat District

the Bhabhar Zone. Higher decadal decline of 2-4 m is observed around Patrampur – Bharatpur in Udham Singh Nagar district and Banbasa in Champawat district. The highest decadal decline of >4 m is observed around Jaspur (Udham Singh Nagar district); and Dhela (Nanital district).

Table 13. Decadal Water Level Fluctuation (August 2005 –August 2015 versus August 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.17	10.16	0.21	7.98	2	10.5	1	5.26	2	10.5	5	26.3	5	26.3	4	21.1
Haridwar	20	0.28	1.33	0.02	4.32	9	45	0	0	0	0	8	40	1	5	2	10
Udham Singh Nagar	26	0.11	2.6	0.1	8.94	5	19.2	1	3.85	0	0	15	57.7	3	11.5	2	7.69
Nainital	7	1.37	4.67	0.33	4.26	1	14.3	0	0	2	28.6	3	42.9	0	0	1	14.3
Champawat	1	--	7.12	--	--	0	0	0	0	1	100	0	0	0	0	0	0
Total	**73**	**0.11**	**10.16**	**0.02**	**8.94**	**17**	**23.3**	**2**	**2.74**	**5**	**6.85**	**31**	**42.5**	**9**	**12.3**	**9**	**12.3**

5.4.1.3 Water Level Fluctuation (November 2006-2015 versus November 2016)

Long-term water level data for 71 monitoring wells is analyzed and is shown in ***Table 14***. A perusal of the data shows that the minimum decadal rise is 0.06 m at Roorkee piezometer in Haridwar District while the maximum decadal rise is 9.1 m at Bhagwanpur in Haridwar District. The minimum decadal decline in water level is 0.14 m at Bana Khera in Udham Singh Nagar district while the maximum decadal decline is 16.25 m at Dhela in Nainital district. The table also indicates that 21 monitoring wells out of 71 (29.58 % of total) had shown decadal rise of 0-2 m, 3 monitoring wells (4.23 % of total) had shown rise of 2-4 m and 4 monitoring wells had shown the highest decadal rise of >4 m. As far as decadal decline in water level is concerned, 26 wells out of 71 (36.62 % of total) had recorded decadal decline in the range of 0-2 m, 6 monitoring wells (8.45% of total) had shown higher decadal decline of 2-4 m and 11 monitoring wells (15.49% of total) had shown the highest decadal decline of >4 m in Uttarakhand in the post-monsoon period.

The decadal water level fluctuation map for average (November 2006 -2015) versus November 2016 is shown in **Fig. 22 (***Dehradun District),* **Fig 23** *(Haridwar District)* and ***Fig. 24*** *(Nainital-Udham Singh Nagar-Champawat section).*

A perusal of **Fig. 22** reveals that minimum decadal rise of 0-2 m is observed as elliptical patch around Rampura – Nanda ki Chowki section and as outlier to the 2-4 m decadal rise water level zone in eastern part of the Doon valley. Higher decadal rise of 2-4 m and highest Rise >4m are observed around Bhaniawala only. The figure also shows that minimum decadal decline of 0-2 m is observed in more than 70% of the Doon valley. The decadal decline in the range of 2-4m is observed as outliers to the >4 m water level zone and as isolated patch at Lal Tappar. The highest decadal decline of >4 m is observed around Redarpur – Shanpur area and Harbanwala – Balliwala area.

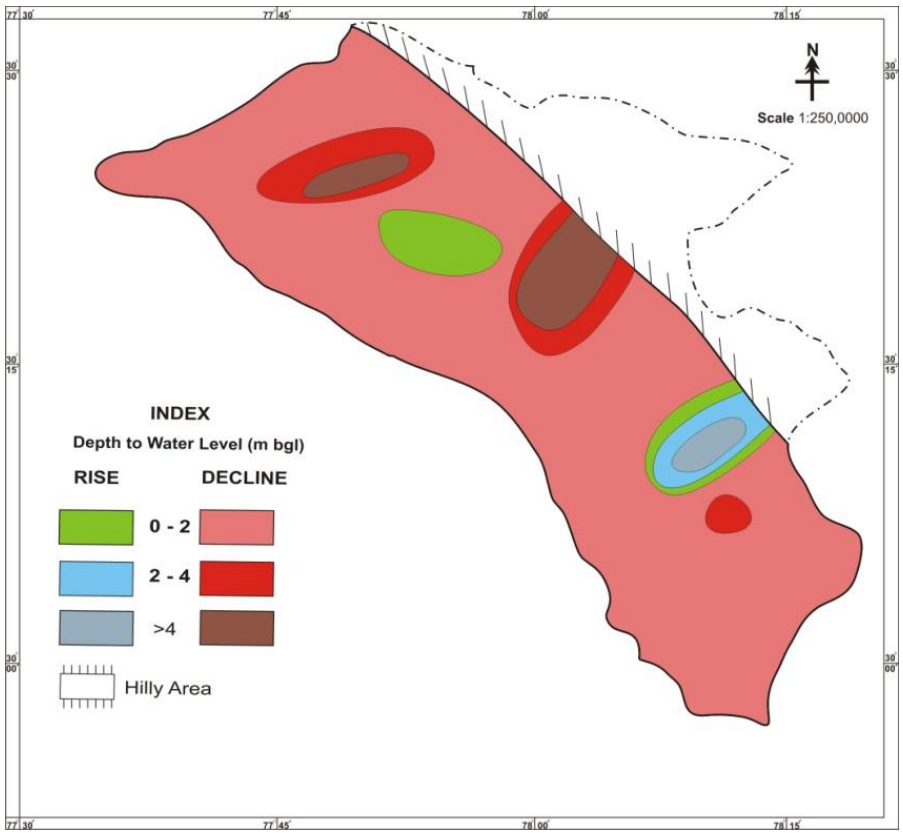


Figure 22 Decadal Water Level Fluctuation Map (November 2006-2015 vs 2016), Dehradun District

A perusal of **Fig. 23** reveals that minimum decadal rise of 0-2 m is observed in >70% parts of Haridwar District. Higher decadal rise of 2-4 m and highest decadal rise of >4 m are not seen in any area as per the available data. The minimum decadal decline of 0-2 m is observed as a circular zone covering Sarai – Rathura section and as linear patch around Sarai – Shapur Shitlakhera section in eastern part of the district. Higher decadal decline of 2-4 m is observed around Lakhnauta and the highest decadal decline of >4 m is observed around Laldhang and Imlikhera only.

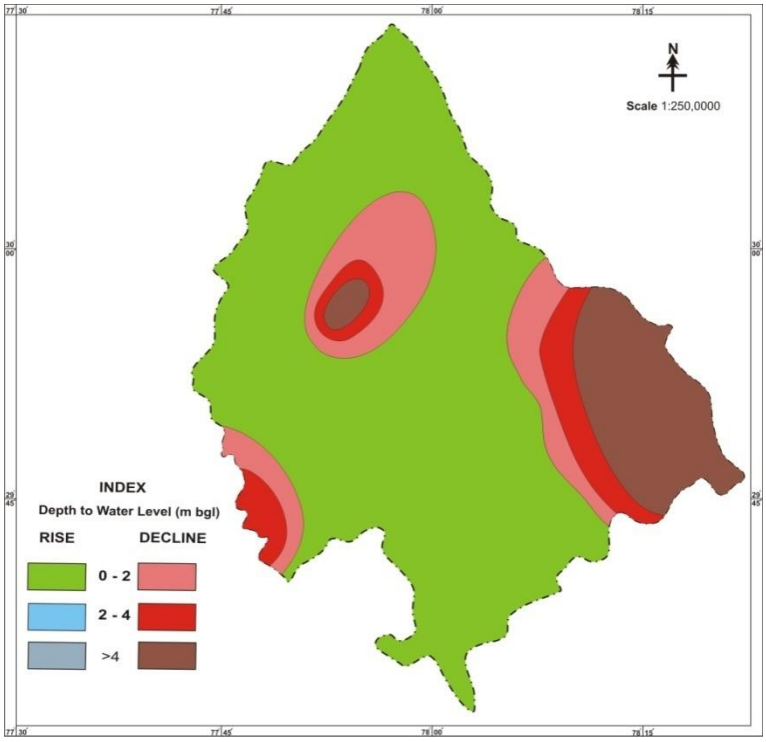


Figure 23 Decadal Water Level Fluctuation Map (November 2006-2015 vs 2016), Haridwar District

Visual interpretation of **Fig. 24** has shown that minimum decadal rise of 0-2 m is observed as isolated patches at Jogipura, Nanna Khera, Sitarganj in Udham Singh nagar and Kathgodham in Nainital District. Higher decadal rise of 2-4 m is seen as isolated patch at Chakarpur in Udham Singh Nagar District. The highest decadal rise of >4 m is observed around the Dhoniya in Nanital district. The minimum decadal decline of 0-2 m is observed in ~65% area of Udham Singh Nagar district falling in the Tarai zone and in ~70% area in the Bhabar zone of Nainital district. Higher decadal decline of 2-4 m is observed around Sultanpur

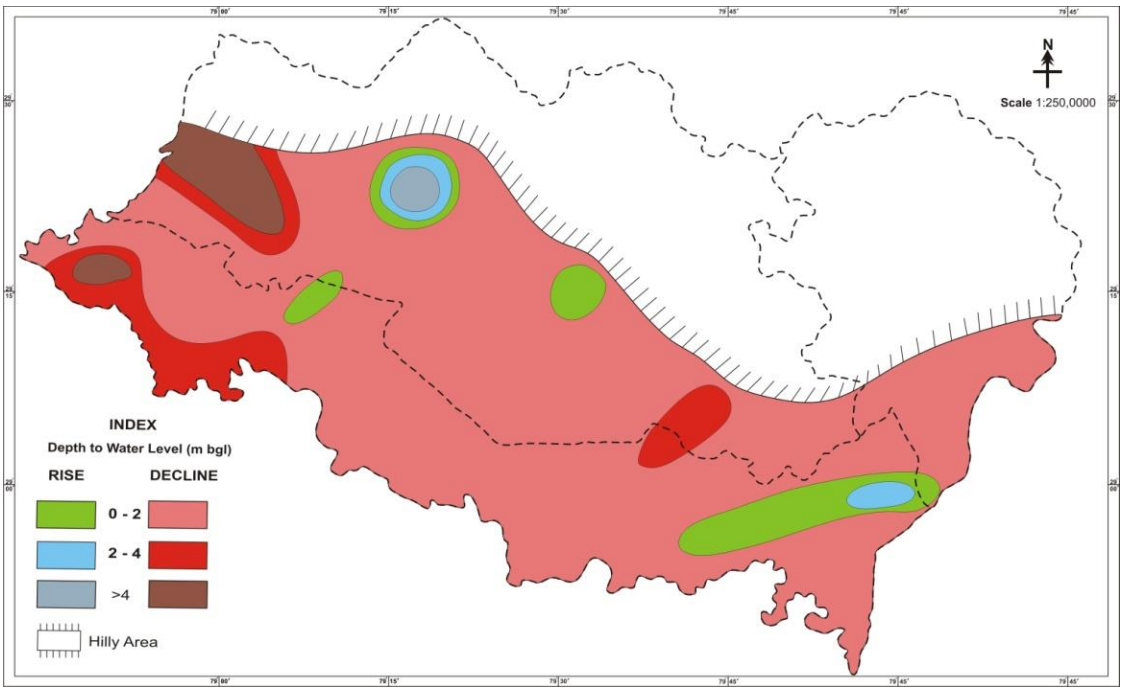


Figure 24 Decadal Water Level Fluctuation Map (November 2006-2015 vs 2016), US Nagar – Nainital - Champawat District

Patti in Udham Singh Nagar district and around Khatbaas; also as concentric patch enclosing >4m zone in the north central and central part of the Bhabhar zone. The highest decadal decline of >4 m is observed around Jaspur in Udham Singh nagar district Dhela – Perru madara in Nanital district.

Table 14. Decadal Water Level Fluctuation (November 2006-November 2015 Versus November 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.61	5.01	0.45	14.83	5	26.32	0	0	1	5.26	5	26.32	2	10.53	6	31.58
Haridwar	24	0.06	9.1	0.28	12.12	11	45.83	2	8.33	2	8.33	5	20.83	2	8.33	2	8.33
Udham Singh Nagar	21	0.24	2.28	0.14	4.93	3	14.29	1	4.76	0	0	15	71.43	1	4.76	1	4.76
Nainital	7	0.29	6.49	1.2	16.25	2	28.57	0	0	1	14.29	1	14.29	1	14.29	2	28.57
Champawat	0	--	--	--	--	0	0	0	0	0	0	0	0	0	0	0	0
Total	**71**	**0.06**	**9.1**	**0.14**	**16.25**	**21**	29.58	**3**	4.23	**4**	5.63	**26**	36.62	**6**	8.45	**11**	15.49

5.4.1.4 Water Level Fluctuation (January 2007-2016 Versus January 2017)

Decadal (long-term) water level data for 75 ground water monitoring wells is analyzed and is given in ***Table 15***. Analysis of the data reveals that the lowest decadal rise is 0.01 m at Beria Daulat in Udham Singh Nagar District whereas the highest decadal rise is 4.12 m at Kathgodham in Nanital District. As far as decadal decline in water level is concerned, the highest is 4.55 m at Redarpur in Dehradun district while the lowest is 0.06m at Judli in Dehradun district.

A perusal of the table also indicates that out of 75 monitoring wells, 23 wells (30.67% of the total number) had shown the minimum decadal rise in the range 0-2 m, 6 wells (8% of the total number) of monitoring wells had shown a higher rise in the range 2-4 m while only 1 well (1.33 % of total) had shown the highest decadal rise of >4 m. The minimum decadal decline in the range of 0-2 m is shown by 30 wells (40 % of total) while 5 wells (6.67%) had shown higher decadal rise of 2-4 m. 10 monitoring well (13.33 %) has recorded the highest decadal decline (>4 m) in Uttarakhand State.

The decadal water level fluctuation map for average (January 2007-2016 versus January 2017) is shown in ***Fig. 25*** *(Dehradun section), Fig.26 (Haridwar section)* and ***Fig. 27*** *(Nainital-Udham Singh Nagar-Champawat section)*.

A perusal of **Fig. 25** (Dehradun District) reveals that minimum decadal rise of 0-2 m is observed as isolated patch around Nanukhera and as outlier to the 2-4m water level (decadal rise) zone around Ramgarh. Higher decadal rise of 2-4m is observed around rampura – Singhniwala section; whereas no area recorded decadal rise of >4m is as per the available data. The minimum decadal decline of 0-2 m is observed in isolated patches at Judli – Herbertpur – Redarpur and Lal Tappar. The decadal decline in the range of 2-4 m is observed en-circling the 0-2m zone in Doon valley. The decadal decline in the range of >4m is observed in majority of the Doon valley.

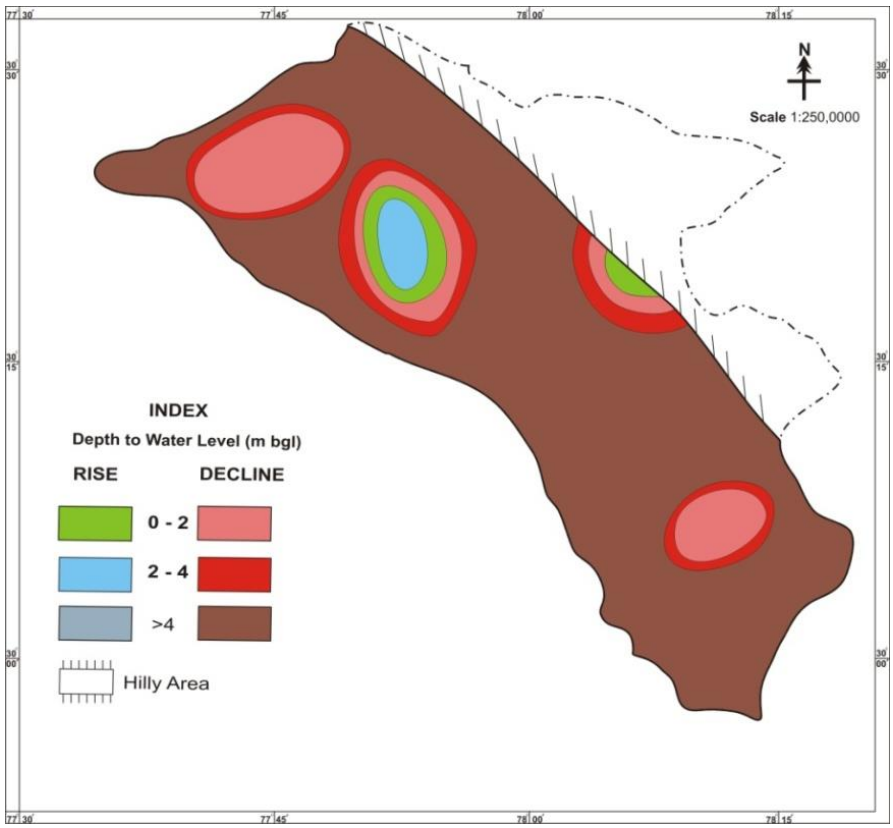


Figure 18 Decadal Water Level Fluctuation Map (January 2007-2016 vs 2017), Dehradun District

A perusal of **Fig. 26** (Haridwar District) reveals that minimum decadal rise of 0-2 m is observed around Sahidwala grant – Iqbalpur – Husainpur – Dallawala in the form a broad zone extending from western part of the district covering central part and reaching till southern part of the district. Higher decadal rise of 2-4 m is observed around Bhikampur only; whereas no monitoring wells has recorded decadal decline of >4m in the Haridwar district. The decadal decline in the range of 0-2m is observed as linear patch covering BandarJud – Sarai – Dhanpura – Shahpur – Shitlakhera and also in south western part of the district. The decadal decline in the range of >4m is observed at Laldhang only as per available data.

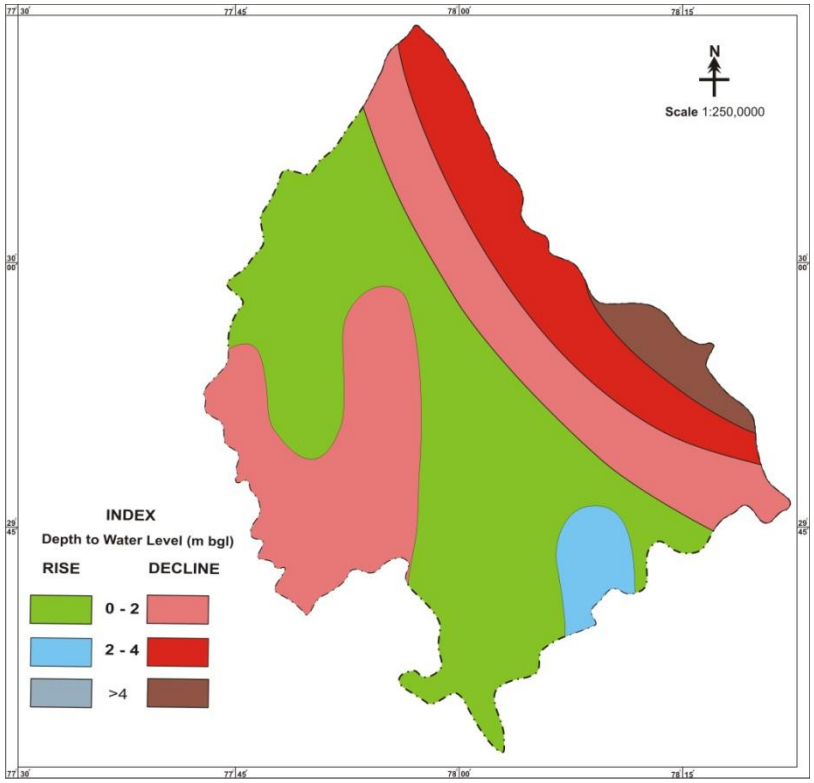


Figure 19 Decadal Water Level Fluctuation Map (January 2007-2016 vs 2017), Haridwar District

Visual interpretation of **Fig. 27***(Nainital-Udham Singh Nagar-Champawat section)* has shown that minimum decadal rise of 0-2 m is observed as long narrow patch around Bara – Gangapur – Beria Daulat – Bana Khera and as isolated patch at Nanak Mata

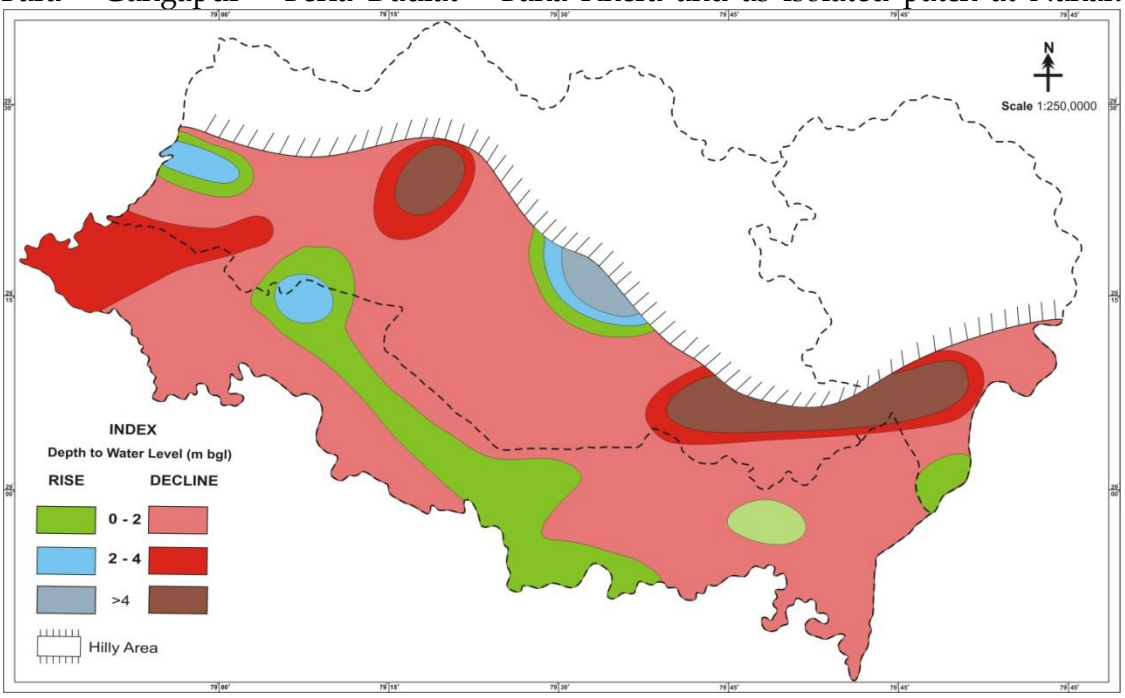


Figure 20 Decadal Water Level Fluctuation Map (November 2007-2016 vs 2017), US Nagar – Nainital - Champawat District

(Udham singh Nagar district) and Banbasa (Champawat district). Higher decadal rise of 2-4 m is observed en-circling the Highest decadal rise >4m zone around kathgodham in Nanital District and as isolated patch around Jogipura in Udham Singh Nagar District. The minimum decadal decline of 0-2 m is observed in Northern and central Part of Tarai Zone, also in major parts of Bhabhar zone. Higher decadal decline of 2-4 m is observed Jaspur - Angadpur – Patrampur (Udham Singh Nagar District) and Peeru Madara (Nainital district). Whereas the highest decadal decline of >4 m is observed around Dhoniya, Khatbass in Nainital District and Bastia in Champawat district.

Table 15. Decadal Water Level Fluctuation (January 2007-January 2016 Versus January 2017)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	17	0.02	2.8	0.06	6.73	3	17.65	2	11.76	0	0.00	5	29.41	1	5.88	6	35.29
Haridwar	23	0.05	3.27	0.26	4.92	8	34.78	2	8.70	0	0.00	11	47.83	1	4.35	1	4.35
Udham Singh Nagar	26	0.01	2.16	0.07	3.07	10	38.46	1	3.85	0	0.00	13	50.00	2	7.69	0	0.00
Nainital	7	0.67	4.12	1.4	7.94	1	14.29	1	14.29	1	14.29	1	14.29	1	14.29	2	28.57
Champawat	2	0.79	--	--	9.72	1	50.00	0	0.00	0	0.00	0	0.00	0	0.00	1	50.00
Total	**75**	**0.01**	**4.12**	**0.06**	**9.72**	**23**	30.67	**6**	8.00	**1**	1.33	**30**	40.00	**5**	6.67	**10**	13.33

5.4.2 YEARLY WATER LEVEL FLUCTUATION

5.4.2.1 Water Level Fluctuation (May 2015 versus May 2016)

The analysis of data for 78 Ground Water Monitoring Wells for May 2015 versus May 2016 is given in ***Table 16.*** A perusal of the table shows that the minimum annual rise in water level is 0.02 m at Landhaura in Haridwar district while the maximum annual rise is 33.62 m at Dhoniya, Nanital district. The minimum annual decline in ground water level is 0.18 m at Hussainpur, Haridwar district while the maximum annual decline is 9.11 m at Dhanauri Patti in Udham Singh Nagar district.

A perusal of ***Table 16*** reveals that out of 78 monitoring wells 26 (33.33% of total) has shown minimum rise in the range 0-2 m whereas higher rise of 2-4 m is shown by 8 monitoring wells (10.26% of the total) and the highest rise of >4 m is recorded by 14 monironing wells (17.95%) for calculating the annual fluctuation in ground water level for the pre-monsoon period. The minimum decadal decline in the range of 0-2 m is shown by 23 out of 78 monitoring wells (29.49% of the total number) had recorded annual decline in the range of 0-2 m. Higher annual decline of 2-4 m is recorded by 3 monitoring wells (3.85% of total) whereas the highest decline of >4 m is recorded by 4 monitoring wells (5.13% of the total number).

The annual water level fluctuation map during the period May 2015 versus May 2016 has been shown in ***Fig. 28*** *(Dehradun District), Figure. 29 (Haridwar section)* and ***Fig. 30*** *(Nainital- Udham Singh Nagar-Champawat section)*.

A perusal of **Fig. 28** (Dehradun District) reveals that minimum Annual rise of 0-2 m is observed as long narrow circular extending from western oart of Doon valley extending upto central part of the valley, covering areas Herbertpur, majra, Redarpur. This zone is also observed as isolated patch at lal Tappar. Higher annual rise of 2-4 m is observed en-circling the 0-2m zone in Doon valley. The highest annual rise of >4 m is observed in more than 50% parts of the Doon valley.The minimum annual decline of 0-2 m is observed in the form of U shaped band in central part of valley (Judli – Sabhawal;a – Shankarpur – Jhajra – Balliwala – Nanukhera section) of Dehradun district. Higher annual decline of 2-4 m is

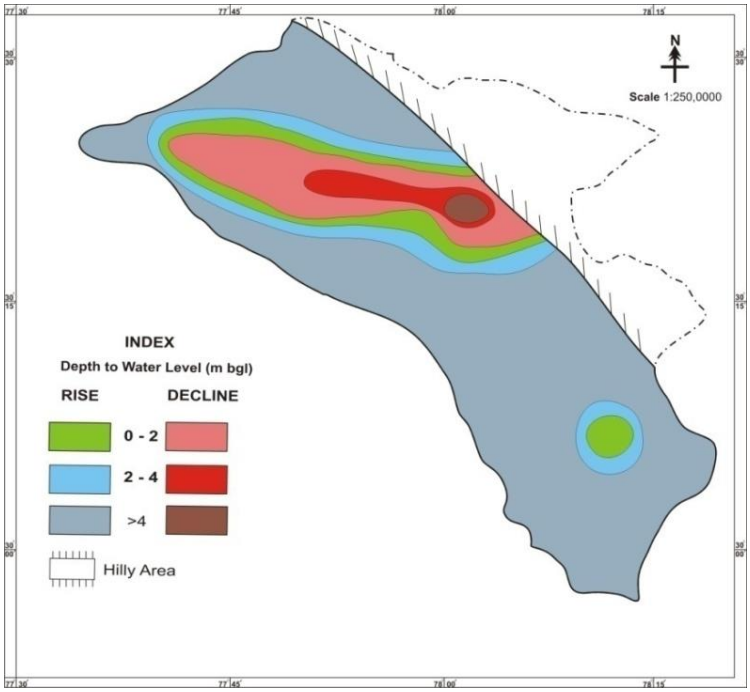


Figure 21 Annual Water Level Fluctuation Map (May 2015 vs 2016), Dehradun District

observed around Rampura and the highest annual decline of >4 m is observed around Harbanswala as per available data.

A perusal of **Fig. 29** (Haridwar District) shows that the more than 50% area is recorded with the water level in the range of 0-2 m. The annual rise of 2-4 m is observed as outlier to the >4m water level zone around Iqbalpur – Rathura. The >4m water level zone is observed around Imlikhera – Bhagwanpur – Chudiala and as isolated patch around Bhikampur. The minimum annual decline of 0-2 m is observed as semicircular patch in eastern part of the district enclosing the 2-4m water level zone; as isolated patche around Sahidwala grant. Higher annual decline of 2-4 m is observed around Manglaur. The highest annual decline of >4 m is observed around Sarai and Lakhnauta in the district.

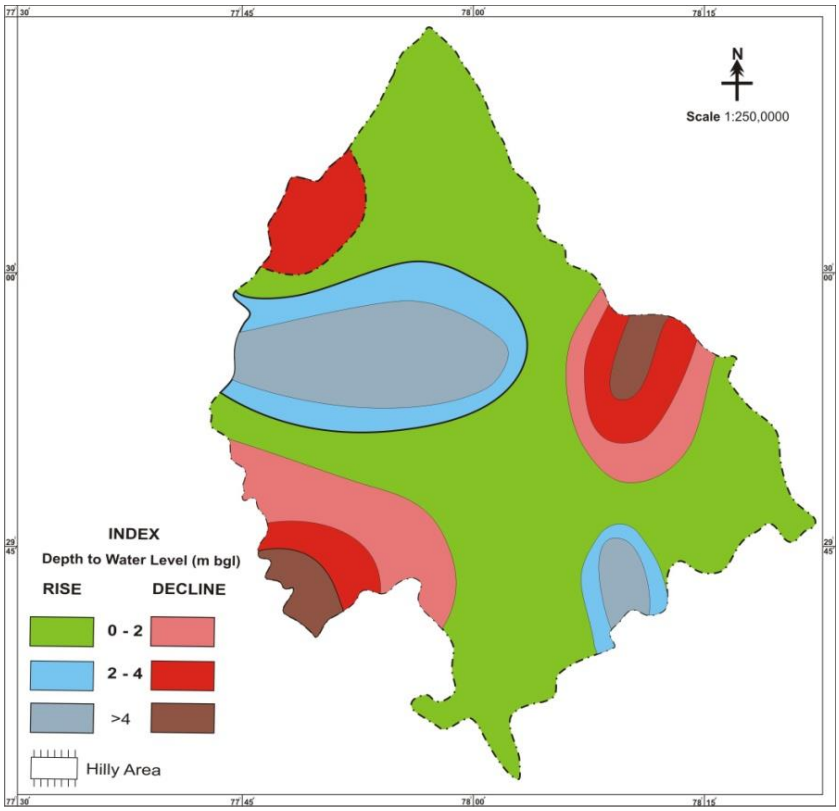


Figure 22 Annual Water Level Fluctuation Map (May 2015 vs 2016), Haridwar District

A study of **Fig. 30** shows that during the pre monsoon period, the minimum annual rise of 0-2 m is observed in major part of Tarai and Bhabhar Zone. Higher annual rise of 2-4 m is observed as outlier to the >4m water level annual rise zone. The highest annual rise of >4 m is observed around Dhoniya – Dhela and Khatbass in Nanital district; and around Bastia in Champawat District. The lowest pre monsoon annual decline of 0-2 m is observed as isolated patches around Kathgodham in Bhabhar Zone and in south eastern part of the Tarai Zone. Higher annual decline of 2-4 m is observed encircling the >4m zone around Jaspur in Udham Singh Nagar District.

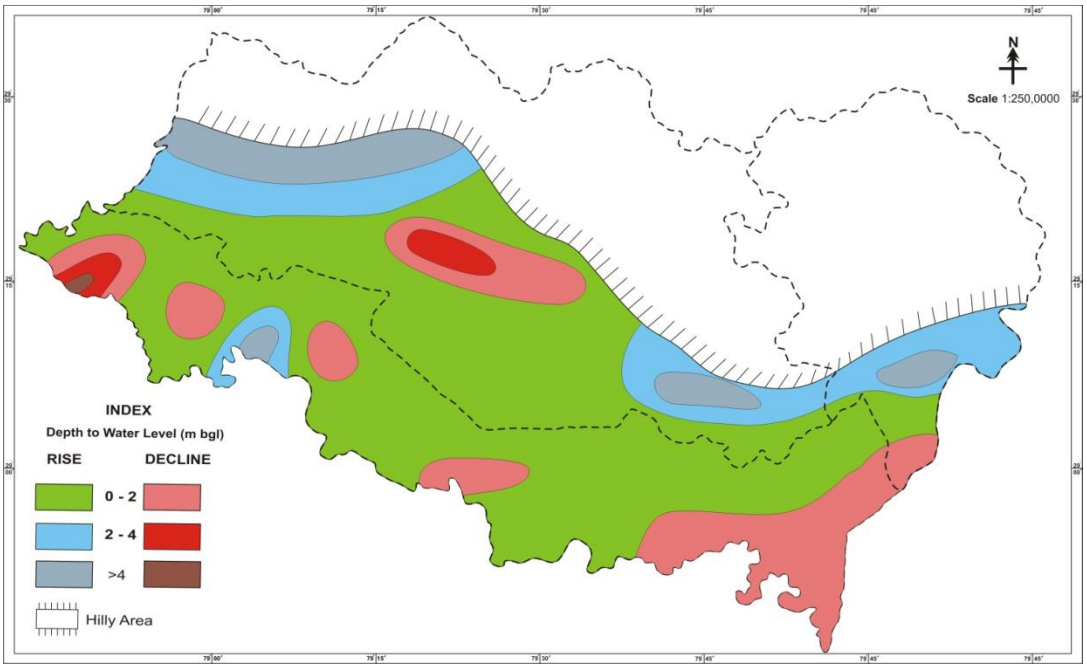


Figure 30 Annual Water Level Fluctuation Map (May 2015 vs 2016), US Nagar – Nainital - Champawat District

Table 16. Annual Water Level Fluctuation (May 2015 Versus May 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.60	17.72	0.20	4.51	5	26.32	1	5.26	2	10.53	8	42.11	2	10.53	1	5.26
Haridwar	24	0.02	9.07	0.18	6.18	7	29.17	4	16.67	5	20.83	6	25.00	0	0.00	2	8.33
Udham Singh Nagar	26	0.06	9.7	0.15	9.11	14	53.85	2	7.69	3	11.54	6	23.08	0	0.00	1	3.85
Nainital	7	2.95	33.62	0.56	3.23	0	0.00	1	14.29	3	42.86	2	28.57	1	14.29	0	0.00
Champawat	2	--	10.59	0.78	--	0	0.00	0	0.00	1	50.00	1	50.00	0	0.00	0	0.00
Total	78	0.02	33.62	0.18	9.11	26	33.33	8	10.26	14	17.95	23	29.49	3	3.85	4	5.13

5.4.2.2 Water Level Fluctuation (August 2015 versus August 2016)

The analysis of annual water level fluctuation data for 73 Ground Water Monitoring Wells for the periods August 2015 and August 2016 is given in ***Table 17.*** Analysis of the fluctuation data indicates that the minimum annual rise of 0.07 m is observed at Goverdhanpur Haridwar district. The maximum annual rise of 21.9 m is observed at Bastia in Champawat district. The lowest annual decline is 0.02 m at Bhikkampur in Haridwar district, whereas the highest decline is 8.93 m at Angadpur in Udham Singh Nagar district.

Analysis of the fluctuation data has indicated that out of 73 monitoring wells, 23 wells (31.51% of total) had shown an annual rise in the range 0-2 m while higher rise of 2-4 m is observed in 2 monitoring well (2.74% of total). The highest rise in the range >4 m is recorded by 10 monitoring wells, which is 13.70% of the total number of wells. It is also seen that majority of monitoring wells (31 out of 73, 42.47% of total) had recorded annual decline in the range of 0-2 m. Higher annual decline of 2-4 m is shown by 2 monitoring wells (2.74% of total) while the highest decline of >4 m is shown by 5 monitoring wells, which is 6.85% of the total number of wells.

The annual water level fluctuation map during the period August 2015 versus August 2016 is shown in ***Fig. 31*** *(Dehradun section),* ***Fig. 32*** *(Haridwar section)* and ***Fig. 33*** *(Nainital-Udham Singh Nagar-Champawat section).*

A perusal of **Fig. 31** indicates that minimum annual rise of 0-2 m is seen in Southeastern part of the Doon valley and as isolated patches around Sabhawala, Rampura. The higher annual rise of 2-4 m is observed as zone en-circling the > 4m water level zone, whereas the highest annual rise of >4 m is observed as long patch covering nanukhera – Bhaniawala section. The minimum annual decline of 0-2 m is observed in more than 70% area of the valley whereas the Higher annual decline of 2-4 m is observed Harbanswala The highest annual decline of >4 m is observed as isolated patches around Balliwala.

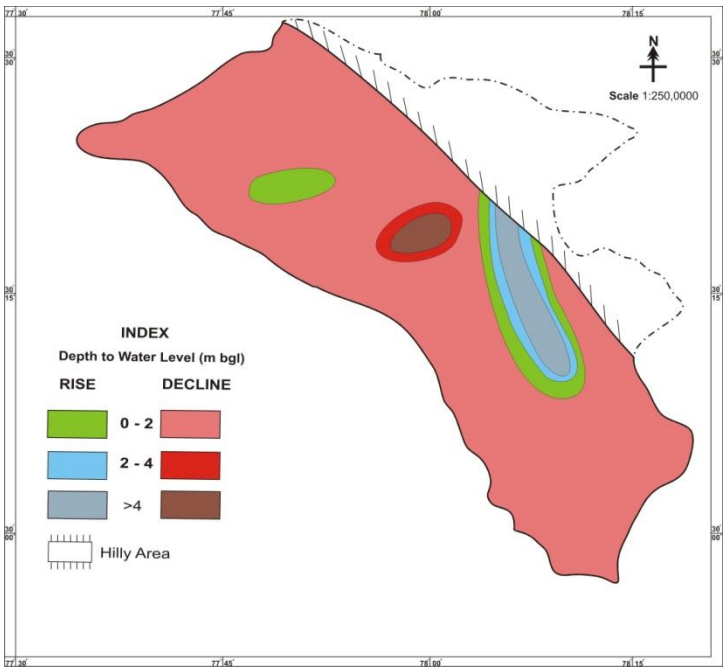


Figure 31 Annual Water Level Fluctuation Map (August 2015 vs 2016), Dehradun District

A perusal of **Fig. 32** indicates that minimum annual rise of 0-2 m is observed in major parts of the district. The 2-4m water level zone is observed as isolated patch around Bandarjud. The highest annual rise of >4 m is observed as around Laldhang. The minimum annual decline of 0-2 m is observed as patches around Bahadrabad, Shapur Shitlakhera, Gurkul Narsen and Dallawala. Higher annual decline of 2-4 m is observed as inlier around Imlikhera and Nizampur to the 0-2m decline water level zone. The highest annual decline of >4 m is observed around the Jhabrera and Lakhnauta.

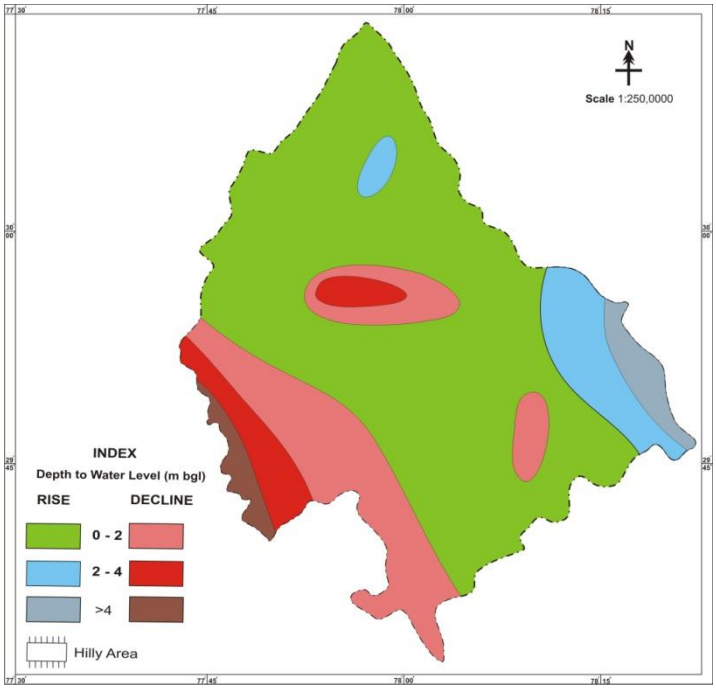


Figure 32 Annual Water Level Fluctuation Map (August 2015 vs 2016), Haridwar District

A perusal of **Fig. 33** indicates that minimum annual rise of 0-2 m is observed around Beria Daulat – Pathar chatta – Shantipuri – Sitarganj in Udham Singh Nagar District and along Kaladhungi in Nanital district. The higher annual rise of 2-4 m is observed around Khatgodham in Nanital district and Majhola in Udham Singh Nagar District. The highest annual rise of >4 m is observed around Khatbass (Nainital District) and Bastia (Champawat district). The minimum annual decline of 0-2 m is observed in central and eastern part of Bhabhar zone and in northern part of Tarai Zone. Higher annual decline of 2-4 m is observed as outlier to the >4m annual decline around Peeru Madara in Nainital district.

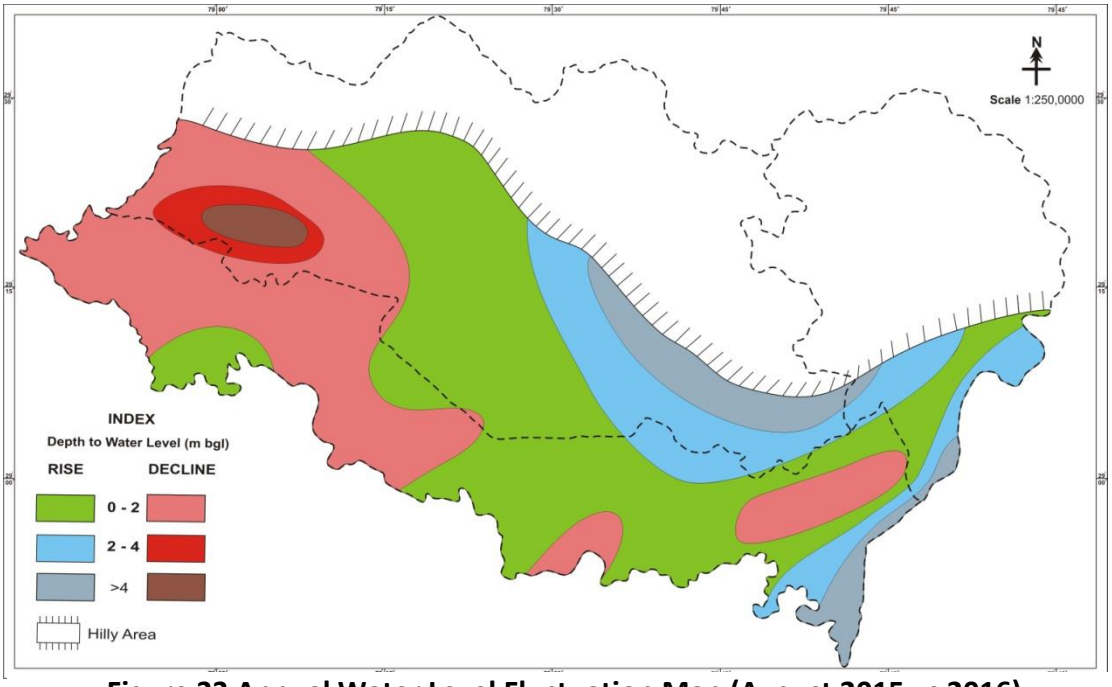


Figure 33 Annual Water Level Fluctuation Map (August 2015 vs 2016), US Nagar – Nainital - Champawat District

Table 17. Annual Water Level Fluctuation (August 2015 versus August 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.09	5.87	0.07	4.54	3	15.79	0	0.00	3	15.79	11	57.89	1	5.26	1	5.26
Haridwar	24	0.07	11.38	0.02	5.35	11	45.83	1	4.17	2	8.33	7	29.17	1	4.17	2	8.33
Udham Singh Nagar	24	0.08	4.96	0.08	8.93	7	29.17	1	4.17	2	8.33	13	54.17	0	0.00	1	4.17
Nainital	5	0.75	7.23	--	4.2	2	40.00	0	0.00	2	40.00	0	0.00	0	0.00	1	20.00
Champawat	1	--	21.9	--	--	0	0.00	0	0.00	1	100.00	0	0.00	0	0.00	0	0.00
Total	73	0.07	21.9	0.02	8.93	23	31.51	2	2.74	10	13.70	31	42.47	2	2.74	5	6.85

5.4.2.3 Water Level Fluctuation (November 2015 versus November 2016)

The analysis of annual water level fluctuation data for 63 Ground Water Monitoring Wells in Uttarakhand is available. Analysis of the data has shown that the lowest annual rise is 0.02m at Sitarganj and Gangapur in Udham Singh Nagar district while the highest annual rise is 17.34 m at Dhanpura in Haridwar district. During the post-monsoon period the lowest annual decline is 0.08 m at Selaqui in Dehradun district while the highest annual decline is 18.19 m at Harbanswala in Dehradun district.

A study of the water level fluctuation data has revealed that 22 monitoring wells out of 63 wells (34.92% of the total number) has recorded a rise in the range of 0-2 m. 6 monitoring well (9.52 % of the total) had shown the higher rise of 2-4 m and 5 monitoring well (7.94 % of the total) had shown the highest rise of>4 m during this period. The 18 no of monitoring wells (28.57% of the total) had recorded an annual decline in the range of 0-2 m during the post monsoon period. 8 wells out of 63 (12.70% of total number) had shown higher decline of water level in the range of 2-4 m whereas only 4 wells (6.35 % of total) had shown the highest annual decline of >4 m in water level.

The annual water level fluctuation map during the period November 2015 versus November 2016 is shown in ***Fig. 34*** *(Dehradun district), Fig.35 (Haridwar section)* and ***Fig. 36*** *(Nainital-Udham Singh Nagar-Champawat section)*.

A perusal of **Fig. 34** has shown that the minimum annual rise in post monsoon period in the range of 0-2 m is observed in more than 70% of the valley. Higher annual rise of 2-4 m is observed as zone encircling the >4m water level zone around Bhaniawala and Nanukhera. The minimum annual decline of 0-2 m is observed around Selaqui, Majra and Tarla Nagal. Higher annual decline of 2-4 m is observed as patches around Redarpur – Herbertpur; Kanwali and Lal Tappar. The highest annual decline of >4 m is observed around Harbanswala – Balliwala area in Doon valley during the post monsoon period.

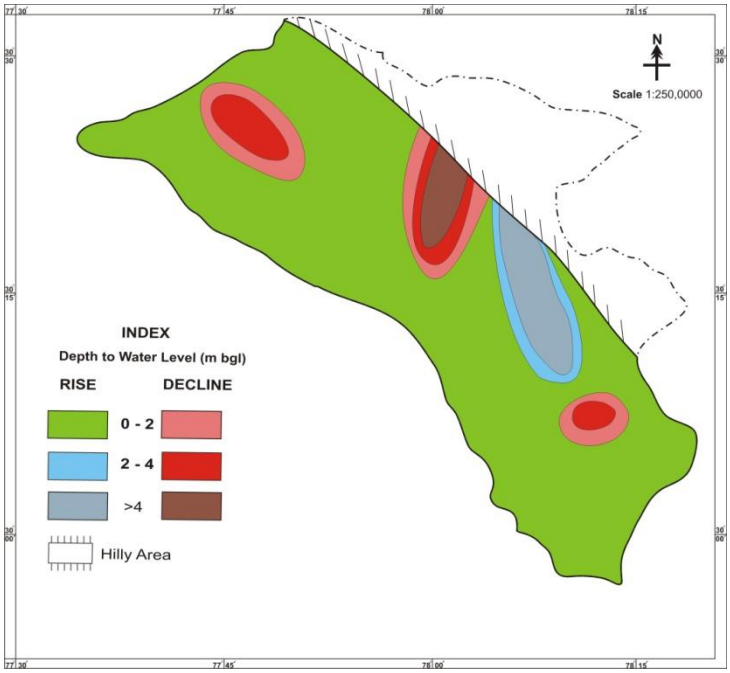


Figure 23 Annual Water Level Fluctuation Map (November 2015 vs 2016), Dehradun District

A perusal of **Fig. 35** has shown that the minimum annual rise in post monsoon period in the range of 0-2 m is major parts of the district; whereas the higher annual rise of 2-4 m is observed as isolated patch Bhagwanpur - Iqbalpur. The highest annual rise of >4 m is observed around Dhanpura in the Haridwar district. The minimum annual decline of 0-2 m is observed as isolated patch around Imlikhera and Rathura. Higher annual decline of 2-4 m is observed as inlier to the 0-2m water level zone around Lakhnauta. The highest annual decline of >4 m is observed around the Laldhang in Haridwar district during the post monsoon period.

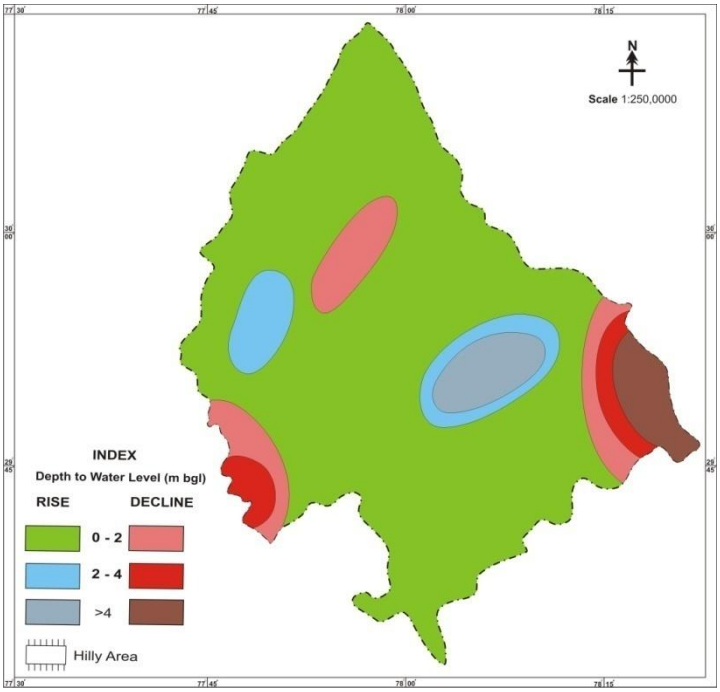


Figure 35 Annual Water Level Fluctuation Map (November 2015 vs 2016), Haridwar District

Interpretation of **Fig. 36** has shown that for the post monsoon period, the minimum annual rise of 0-2 m is observed in central and eastern part of the Tarai and Bhabar zone; and also as isolated patch around Kashipur – Patrampur in Udham Singh Nagar District. Higher annual rise of 2-4 m is observed as linear patch around Khatbass (Nainital District) and Chakarpur (Udham Singh Nagar District). The highest annual rise of >4 m is observed as inlier of the 2-4m water level rise zone around Dhoniya (Nainital district). The minimum annual decline of 0-2 m is observed around western part and

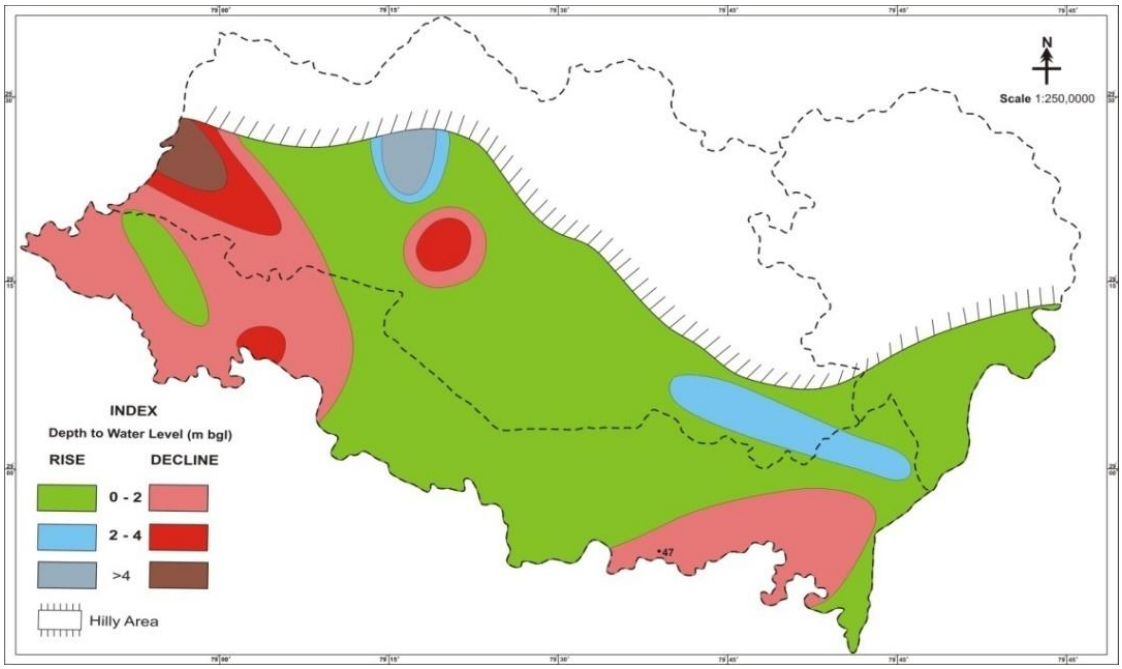


Figure 36 Annual Water Level Fluctuation Map (November 2015 vs 2016), US Nagar – Nainital - Champawat District

southern parts of Tarai zone in Udham Singh Nagar district; also in northern part of Bhabhar Zone in Nanital district. Higher annual decline of 2-4 m is observed as the isolated patch around Sultanpur Patti (Udham Singh Nagar district); Peeru Madara and Kaladhungi in Nainital District. The highest annual decline of >4 m is observed around Dhela in Nainital district.

Table 18. Annual Water Level Fluctuation (November 2015 Versus November 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.11	8.99	0.08	18.19	6	31.58	2	10.53	2	10.53	3	15.79	4	21.05	2	10.53
Haridwar	18	0.11	17.34	0.12	13.98	6	33.33	2	11.11	2	11.11	6	33.33	1	5.56	1	5.56
Udham Singh Nagar	19	0.02	3.95	0.10	2.50	8	42.11	1	5.26	0	0.00	9	47.37	1	5.26	0	0.00
Nainital	7	1.98	9.50	2.32	13.08	2	28.57	1	14.29	1	14.29	0	0.00	2	28.57	1	14.29
Champawat	0	--	--	--	--	0	0	0	0	0	0	0	0	0	0	0	0
Total	63	0.02	17.34	0.08	18.19	22	34.92	6	9.52	5	7.94	18	28.57	8	12.70	4	6.35

5.4.2.4 Water Level Fluctuation (January 2016 versus January 2017)

The analysis of water level data of 75 ground water monitoring wells for the period January 2016 versus January 2017 is given in ***Table 19.*** A perusal of the table indicates that the minimum annual rise is 0.10 m at Bandarjud in Haridwar district whereas the maximum annual rise is 17.58 m at Majra in Dehradun district. The minimum annual decline is found to be 0.05 m at Ramgarh in Dehradun district whereas the maximum decline is 20.56 m at Khatbaans in Nanital district.

A perusal of the table also reveals that out of 75 monitoring wells, 37 wells (49.33%) have recorded the minimum annual rise in the range 0-2 m whereas 5 wells n(6.67% of total wells) had shown higher rise in the range 2-4 m. 4 no of monitoring wells (5.33% of the total) had recorded the highest annual rise of >4 m during the period January 2016 to January 2017. Lowest annual decline of 0-2 m is recorded by 24 monitoring wells (32% of total) while 2 wells (2.67%) had recorded higher decline in the range of 2-4 m. The highest decline of >4 m is shown by 3 no of monitoring well (4% of total).

The annual water level fluctuation map during the period January 2016 versus January 2017 is shown in ***Fig. 37*** *(Dehradun district), Fig. 38 (Haridwar district)* and ***Fig. 39*** *(Nainital-Udham Singh Nagar-Champawat section)*.

Visual interpretation of **Fig. 37** has shown that the minimum annual rise in the range of 0-2 m is observed as isolated patches around the Lal Tappar, Chhorba – Rampura. Higher annual rise of 2-4 m is observed at Singhniwala. Whereas the highest annual rise of >4 m is observed Majra. The minimal annual decline of 0-2 m is observed in the more than 70% of the valley. Higher annual decline of 2-4 m is observed as outlier to the >4m water level decline which is observed as isolated patch at Sabhawala.

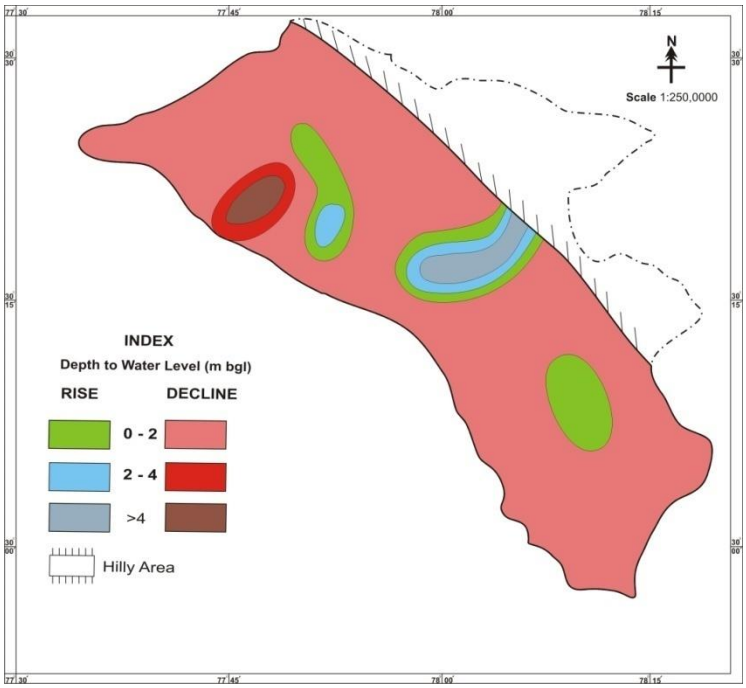


Figure 37 Annual Water Level Fluctuation Map (January 2016 vs 2017), Dehradun District

Visual interpretation of **Fig. 38** has shown that the minimum annual rise in the range of 0-2 m is observed in more than 75% of the district. Higher annual rise of 2-4 m is observed as isolated around Bhagwanpur and Bhikampur. The highest annual rise of >4 m is not observed in Haridwar district. The minimal annual decline of 0-2 m is observed as isolated patches around Imlikhera – Sahidwala Grant and Jhabrera – Lakhnauta – Gurkul Narsen and Dallawala. Higher annual decline of 2-4 m is observed as isolated patches around Laldhang in Haridwar district. The highest annual decline of >4 m is not recorded in any monitoring station in Haridwar district.

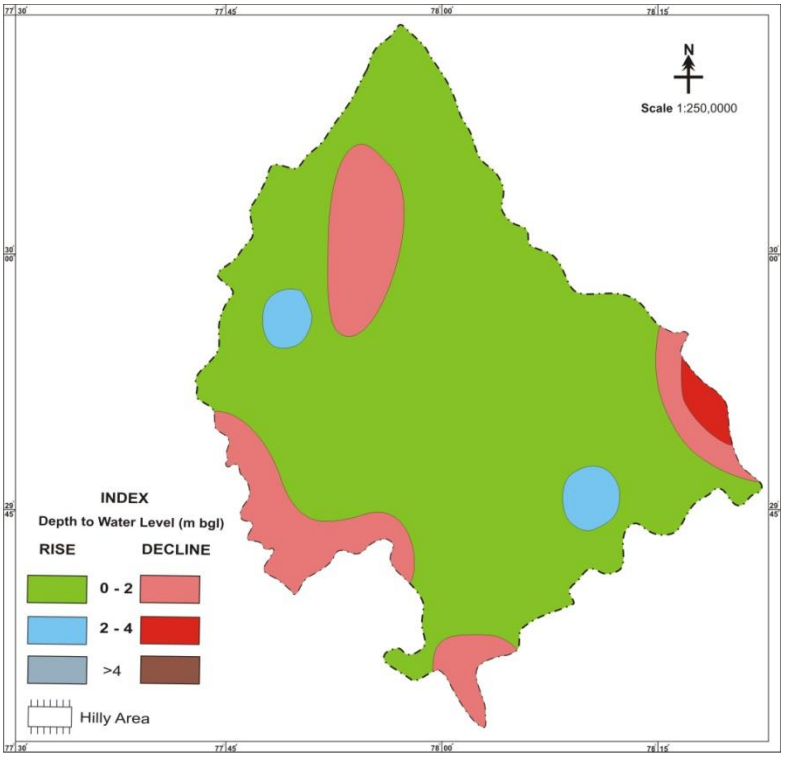


Figure 38 Annual Water Level Fluctuation Map (January 2016 vs 2017), Haridwar District

A perusal of **Fig. 39** indicates that the minimum annual rise of 0-2 m is observed in majority of the Bhabhar and Tarai zone. Higher annual rise of 2-4 m is observed as isolated patches around Bhagwanpur and Sultanpur Patti in Udham Singh Nagar District. The highest annual rise of >4 m is observed only around Kathgodham in Nainital district. The minimum annual decline of 0-2 m is observed around Patrampur, Bara, Bazpur, Sitarganj in Udham Singh Nagar

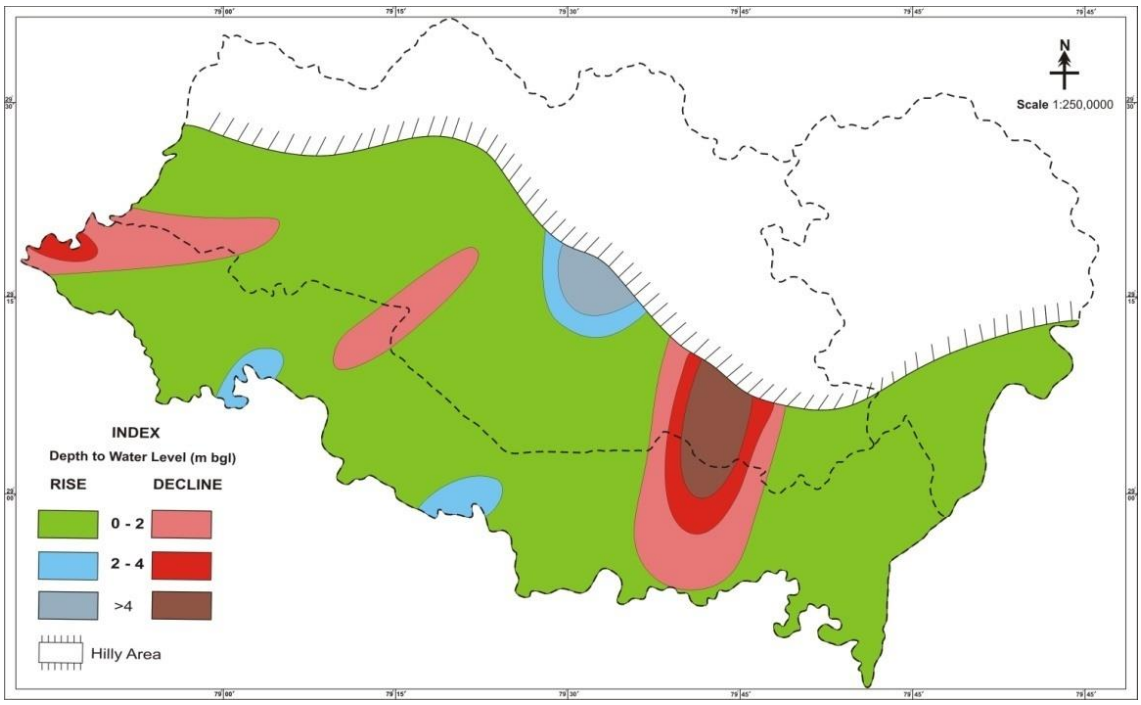


Figure 39 Annual Water Level Fluctuation Map (November 2015 vs 2016), US Nagar – Nainital - Champawat District

District and Peeru Madara, Kaladhungi in Nainital District. The higher annual decline of 2-4 m is observed around Angadpur in Udham Singh Nagar District and the highest annual decline of >4 m is observed around Khatbass in Nainital District.

Table 19. Annual Water Level Fluctuation (January 2016 versus January 2017)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.33	17.58	0.05	12.41	5	26.32	1	5.26	2	10.53	9	47.37	0	0.00	2	10.53
Haridwar	23	0.10	3.11	0.10	3.97	12	52.17	2	8.70	0	0.00	8	34.78	1	4.35	0	0.00
Udham Singh Nagar	26	0.17	2.84	0.15	2.03	18	69.23	2	7.69	0	0.00	5	19.23	1	3.85	0	0.00
Nainital	5	5.20	9.99	1.16	20.56	0	0.00	0	0.00	2	40.00	2	40.00	0	0.00	1	20.00
Champawat	2	0.59	1.88	--	--	2	100.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	75	0.10	17.58	0.05	20.56	37	49.33	5	6.67	4	5.33	24	32.00	2	2.67	3	4.00

5.4.3 SEASONAL WATER LEVEL FLUCTUATION

5.4.3.1 Water Level Fluctuation (May 2016 versus August 2016)

The seasonal fluctuation of water level during the period May 2016 versus August 2016 for 76 ground water monitoring wells in Uttarakhand State is given in ***Table 20.*** A perusal of the fluctuation data has shown that the minimum seasonal rise in ground water level was 0.19m at Balliwala in Dehradun district whereas the maximum rise was 12.34 m at Bastia in Champawat district. The minimum seasonal decline was 0.24 m at Chudiala in Haridwar district while the maximum decline was 28.50 m at Dhoniya in Nanital district.

The perusal of Table 20 also reveals that rise in the range of 0-2 m was shown by 29 monitoring wells, which was 38.16% of the total number of wells. Higher rise in the range 2-4 m was shown by 17 wells (22.37% of total) while the highest rise of >4 m was shown by 16 wells (21.05% of total). The lowest seasonal decline of 0-2 m was recorded by 8 monitoring wells (10.53% of total). Higher seasonal decline of 2-4 m was shown by 3 monitoring wells, which was only 3.95% of the total number of wells during the period May versus August 2016. The highest seasonal decline of >4 m was recorded by 3 monitoring wells (3.95% of total).

The seasonal water level fluctuation map during the period May 2016 versus August 2016 is shown in ***Fig. 40*** *(Dehradun District),* ***Fig. 41*** *(Haridwar section)* and ***Fig. 42*** *(Nainital-Udham Singh Nagar-Champawat section).*

Visual interpretation of **Fig. 40** has shown that the lowest seasonal fluctuation of 0-2 m is observed in major parts of the Doon valley. The Seasonal rise of 2-4 m is observed as patches around Herbertpur – Judli and Shankarpur – Ramgarh – Balliwala area. The highest seasonal rise of water level (>4 m) is extensively found in Sabhaweala – Rampura – Jhajra – Harbanswala – section and also as isolated patch around Bhaniawala. No monitoring stations recorded any seasonal decline in Doon valley.

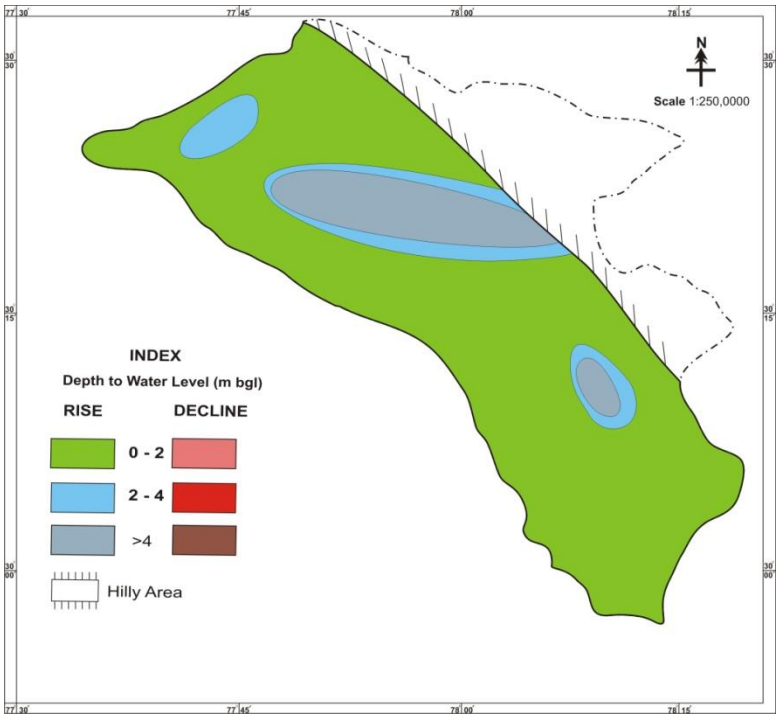


Figure 40 Water Level Fluctuation Map (May 2016 vs August 2016), Dehradun District

Visual interpretation of **Fig. 41** has shown that the lowest seasonal fluctuation of 0-2 m is observed dominantly in the eastern, south eastern and southern part of the district. The Seasonal rise of 2-4 m is observed around Bhupatwala – Dhanpura – Shapur Shitlakhera; Sahidwala Grant – Buggawala & Husainpur – Laknauta area. The highest seasonal rise of water level (>4 m) is observed in isolated patch around Gurkul narsen and laldhang. The lowest seasonal decline of 0-2 m is observed as dominantely in the northern part of the district. Higher seasonal decline of 2-4 m is observed as outlier to the >4m zone which is observed around the Bahadrabad.

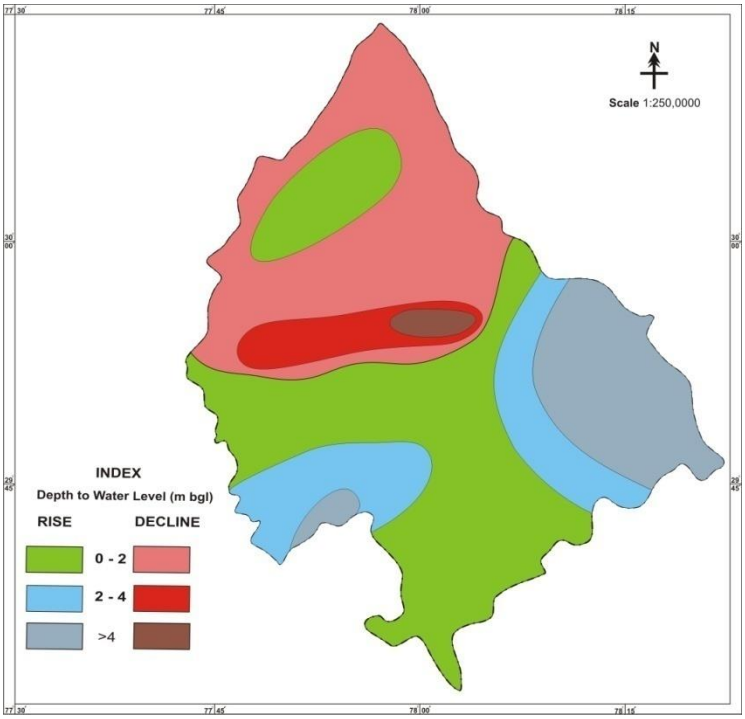


Figure 41 Water Level Fluctuation Map (May 2016 vs August 2016), Haridwar District

A perusal of **Fig. 42** indicates that the lowest positive seasonal fluctuation of 0-2 m is observed in the major parts of Tarai and Bhabar zone. Higher seasonal rise of 2-4 m is observed as patch in and around Kashipur – Bazpur – Bhagwanpur – Sitarganj. The highest seasonal rise of water level (>4 m) is observed as isolated patch at Gangpur (Udham Singh Nagar district) and Bastia (Champawat district). The lowest seasonal decline of 0-2 m is observed as isolated patches at Chakarpur, Kiccha, Patrampur in Udham Singh Nagar district. Seasonal decline of 2-4m is observed as inlier to the seasonal decline zone of >4m at Angadpur in Udham Singh Nagar district.

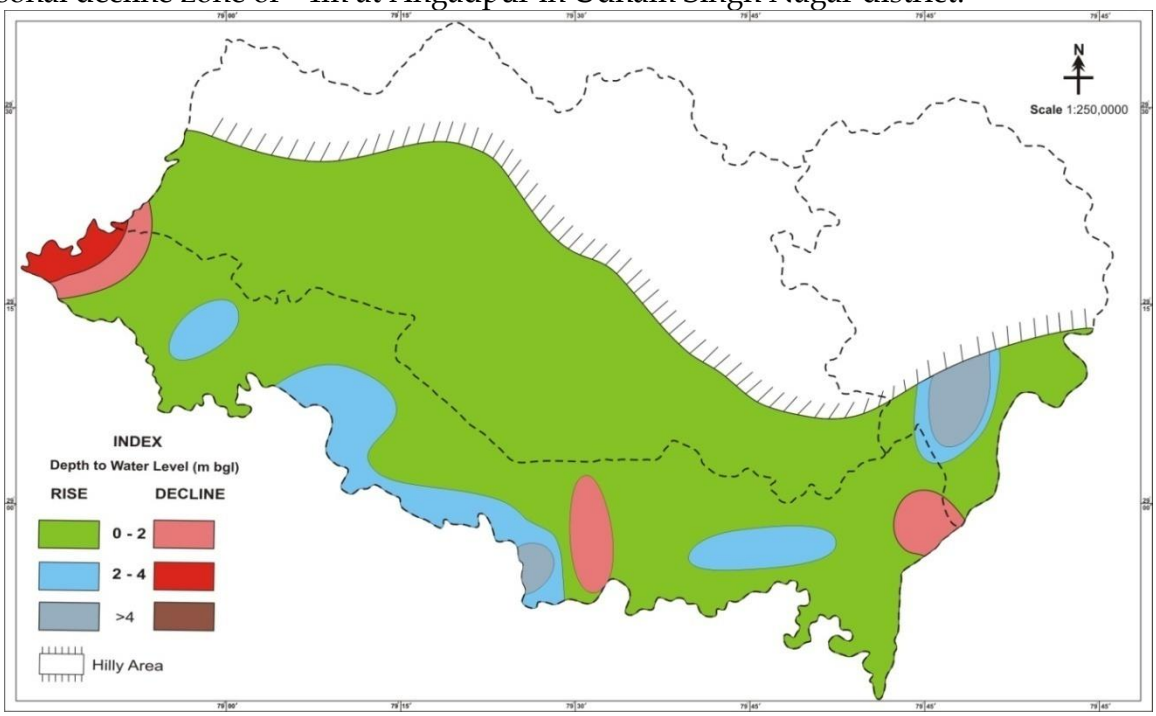


Figure 42 Water Level Fluctuation Map (May 2016 vs August 2016), US Nagar – Nainital - Champawat District

Table 20. Seasonal Water Level Fluctuation (May 2016 Versus August 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.19	11.84	--	--	6	31.58	3	15.79	10	52.63	0	0.00	0	0.00	0	0.00
Haridwar	24	0.31	9.64	0.24	2.74	8	33.33	7	29.17	3	12.50	4	16.67	1	4.17	1	4.17
Udham Singh Nagar	26	0.40	4.75	0.90	7.64	14	53.85	6	23.08	1	3.85	4	15.38	0	0.00	1	3.85
Nainital	6	1.50	8.58	2.30	28.50	1	16.67	1	16.67	2	33.33	0	0.00	2	33.33	0	0.00
Champawat	1	--	12.34	--	--	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	100.00
Total	76	0.19	12.34	0.24	28.50	29	38.16	17	22.37	16	21.05	8	10.53	3	3.95	3	3.95

5.4.3.2 Water Level Fluctuation (May 2016 versus November 2016)

The water level fluctuation data of May 2016 was compared with that of November 2016 for 121 ground water monitoring wells in Uttarakhand and the result is given in ***Table 21.*** Analysis of the fluctuation data for the period May-November (pre-monsoon versus post-monsoon) indicates that the minimum seasonal rise was 0.10 m at Tukri in Udham Singh Nagar district while the maximum was 10.66 m at Purkulgaon in Dehradun district. The annual decline was 0.04 m at Kanakpur in Udham Singh Nagar district whereas the maximum decline was 18.10 m at Dhoniya in Nanital district.

A perusal of the fluctuation data also shows that seasonal rise of 0-2 m was shown by 50 monitoring wells out of 121 (41.32%), that in the range of 2-4 m by 20 monitoring wells (16.53 % of total) and that in the range of >4 m by 16 wells (13.22% of total) in Uttarakhand State. Seasonal decline in the range 0-2 m was recorded by 14 monitoring wells (11.57% of total). Higher seasonal decline in the range of 2-4 m had been recorded by 10 no of monitoring wells (8.26% of total) and the highest decline of >4 m was recorded by 11 (9.09%) monitoring well.

The seasonal water level fluctuation map during the period May 2016 versus November 2016 is shown in ***Fig. 43*** *(Dehradun district),* ***Fig.44*** *(Haridwar District)* and ***Fig. 45*** *(Nainital-Udham Singh Nagar-Champawat section).*

Visual interpretation of **Fig. 43** has revealed that the lowest seasonal rise of 0-2 m is observed in major parts of the Doon valley. Higher seasonal rise of 2-4 m is observed as outlier to the >4m seasonal rise zone. The highest seasonal rise of >4 m is observed around Dhakrani – Dharmawala – Barotiwala; Kuanwala - Bhaniawala and as isolated patch around Jhajra and Khandgaon. Seasonal decline in the range of 0-2m is observed as outliers to the Seasonal decline in the range of 2-4 m, which are around Majra, Dandhi and Vikasnagar. The seasonal decline in the range of >4 m is observed around Balliwala and Khandgaon.

Figure 43 Water Level Fluctuation Map (May 2016 vs November 2016), Dehradun District

Visual interpretation of **Fig. 44** has revealed that the lowest seasonal rise of 0-2 m is observed dominantly in central, southern and southern eastern part. Higher seasonal rise of 2-4 m is observed as patches around Hussainpur Laldhang, sahidwala grant. The highest seasonal rise of >4 m is observed around Landhaura – Libraheri and Bhagwanpur in the district as per available data of the monitoring wells. The lowest seasonal decline of 0-2 m is observed in northern part of the district and as isolated patch around Bhogpur.

The seasonal decline in the range of 2-4 m is observed as isolated patch around Chudiala – Iqbalpur and Imlikhera - Bahadrabad and >4 m is not recorded in any of the monitoring stations in the district.

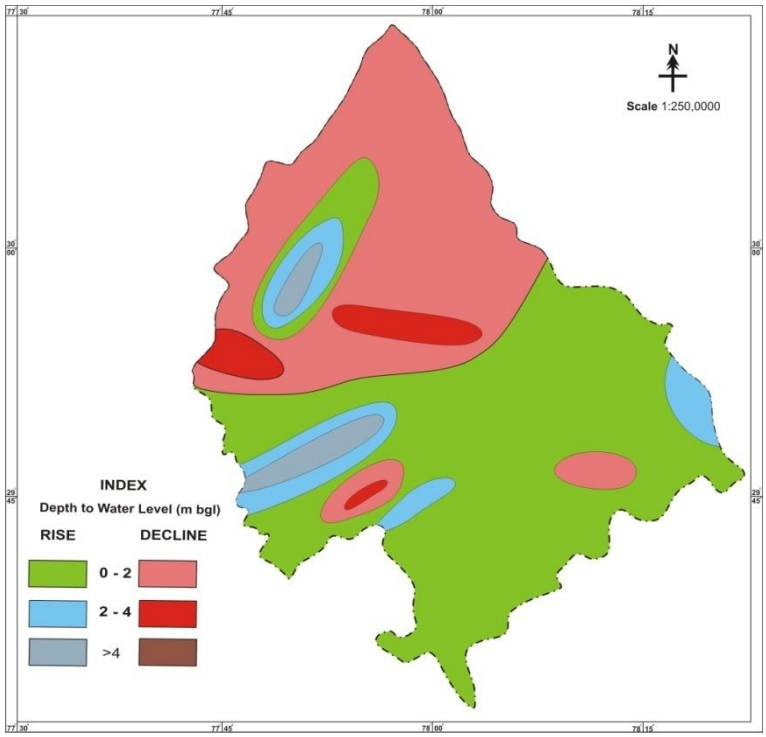


Figure 44 Water Level Fluctuation Map (May 2016 vs November 2016), Haridwar District

A perusal of **Fig. 45** has shown that the lowest positive seasonal fluctuation of 0-2 m is observed in major parts of Bhabhar and Tarai zone. Higher seasonal rise of 2-4 m is observed as patches around Jaspur – Durgapur - Missarwala - Sitarganj and Chakarpur in Udham Singh Nagar district and Kaladhungi – Kathgodham in Nainital district. The highest seasonal rise of water level (>4 m) is observed around Peeru Madara in Nainital district. The lowest seasonal decline of 0-2 m is observed as patches around Mahabir Nagar, Sarasariya, Kanakpur, Kalyanpur in Udhamsingh nagar district and as curvilinear patch in northern Bhabar zone. Seasonal decline of 2-4m is observed as outlier to the seasonal decline zone of >4m at Sultanpur Patti in Udham Singh nagar district and around Dhela – Ram Nagar – Dhoniya – Khat bass in Nainital district.

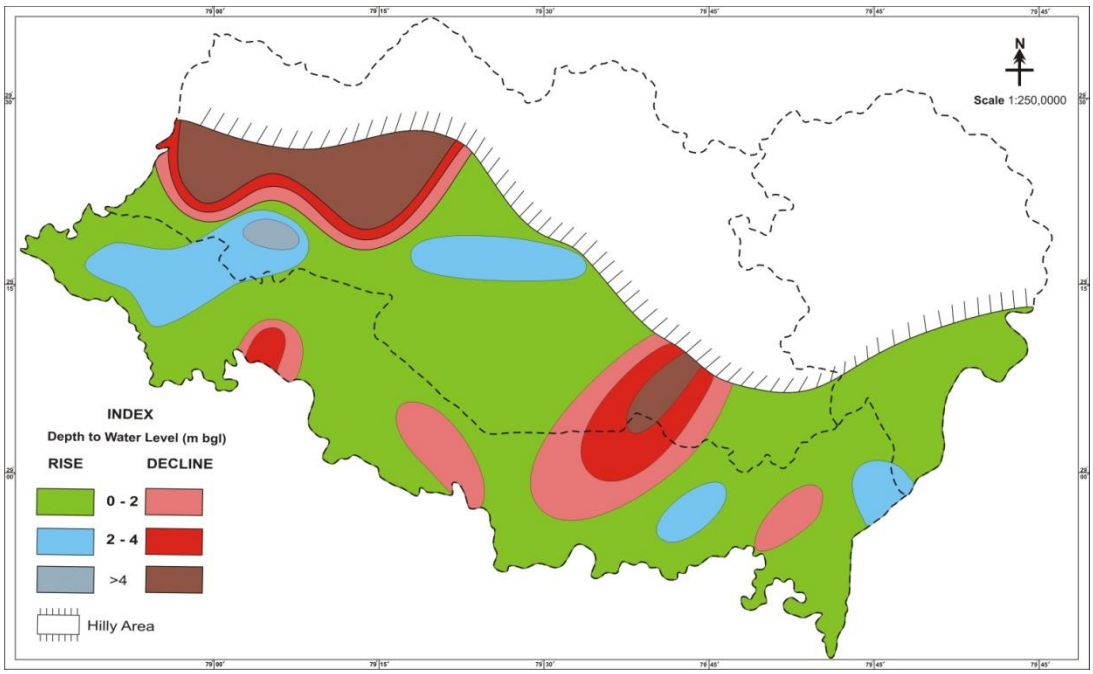


Figure 45 Water Level Fluctuation Map (May 2016 vs November 2016), US Nagar – Nainital - Champawat District

Table 21. Seasonal Water Level Fluctuation (May 2016 Versus November 2016)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	42	0.15	16.66	0.16	8.78	13	30.95	7	16.67	12	28.57	2	4.76	3	7.14	5	11.90
Haridwar	32	0.15	6.95	0.12	3.19	14	43.75	5	15.63	3	9.38	5	15.63	5	15.63	0	0.00
Udham Singh Nagar	36	0.10	3.40	0.04	3.30	22	61.11	5	13.89	0	0.00	7	19.44	2	5.56	0	0.00
Nainital	11	0.95	4.66	4.20	18.10	1	9.09	3	27.27	1	9.09	0	0.00	0	0.00	6	54.55
Champawat	--	--	--	--	--	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	121	0.10	16.66	0.04	18.10	50	41.32	20	16.53	16	13.22	14	11.57	10	8.26	11	9.09

5.4.3.3 Water Level Fluctuation (May 2016 Versus January 2017)

The seasonal water level fluctuation for the period May 2016 versus January 2017 is available for 78 monitoring wells in Uttarakhand State. The water level fluctuation data is given in ***Table* 22.** A perusal of the table indicates that the minimum rise was 0.13 m at Dalawala in Haridwar District while the maximum fluctuation was 19.37 m at Majra in Dehradun district. The minimum seasonal decline in ground water level was 0.07 m at Sultanpur Patti in Udham Singh Nagar District while the maximum decline was 28.15 m at Dhoniya in Nanital District.

A perusal of **Table 22** also reveals that that the lowest seasonal rise of 0-2 m was shown by 37 monitoring wells (47.44% of total) whereas higher rise of 2-4 m was shown by 15 wells (19.23% of total). The highest seasonal rise of >4 m was shown by 6 wells, which was 7.69% of the total wells. Seasonal decline in the range of 0-2 m was shown by 10 monitoring wells (12.82% of total) while higher decline of 2-4 m was shown by 4 wells (5.13% of total). The highest decline of >4 m was recorded by 6 monitoring wells (7.69% of total) for which the data is available in Uttarakhand State during the period May 2016 versus January 2017.

The seasonal water level fluctuation map during the period May 2016 versus January 2017 is shown in ***Fig. 46*** *(Dehradun district),* ***Fig 47(****Haridwar district)* and ***Fig. 48*** *(Nainital-Udham Singh Nagar-Champawat section)*.

Interpretation of **Fig. 46** indicates that the minimum decadal rise of 0-2 m is observed in more than 70% area of the Doon valley. The seasonal rise of 2-4 m is observed as isolated patch around Singhniwala, Rampura and Lal Tappar. The highest seasonal rise of >4 m is observed around Bhaniawala. The lowest seasonal decline of 0-2 m is observed as circular isolated patch around Herbertpur, Shankarpur and Harbanswala in the doon valley. The seasonal decline in the range of 2-4 m is recorded as inlier of the 0-2m seasonal decline zone. Whereas, the seasonal decline >4 m is observed around Sabhawala and Bhaniawala.

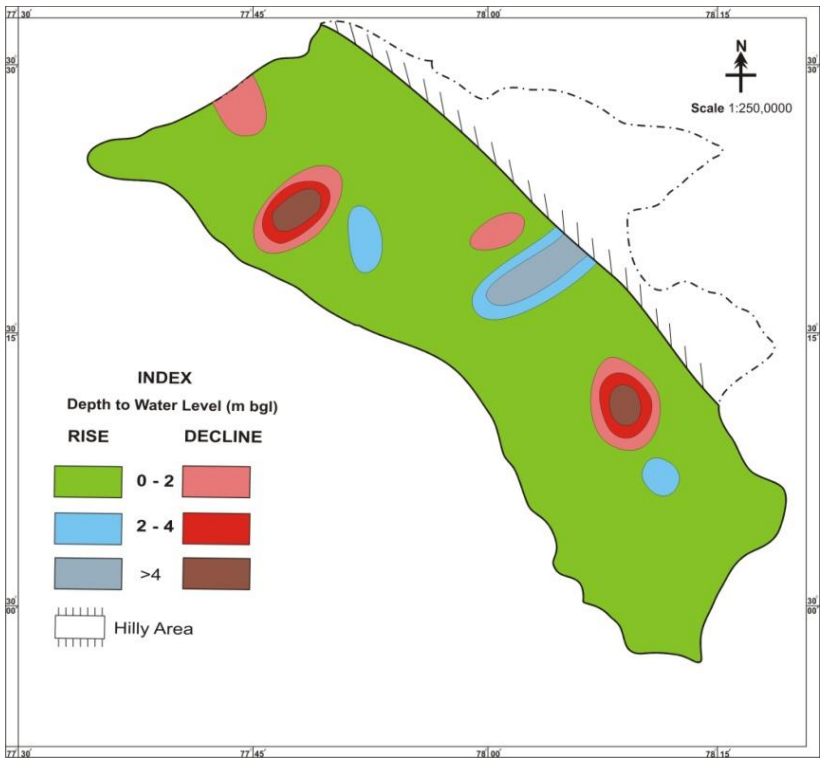


Figure 46 Water Level Fluctuation Map (May 2016 vs January 2017), Dehradun District

Visual interpretation of **Fig. 47** has revealed that the lowest seasonal rise of 0-2 m is observed dominantly in central, southern and western part. Higher seasonal rise of 2-4 m is observed as linear patches around Hussainpur – Lakhnauta and Dhanpura. The highest seasonal rise of >4 m is observed around Laldhang in the district as per available data of the monitoring wells. The lowest seasonal decline of 0-2 m is observed in northern part of the district. The seasonal decline in the range of 2-4 m is observed as isolated patch around Rathura – Bahadrabad and Iqbalpur and >4 m is recorded only at chudiala in the district.

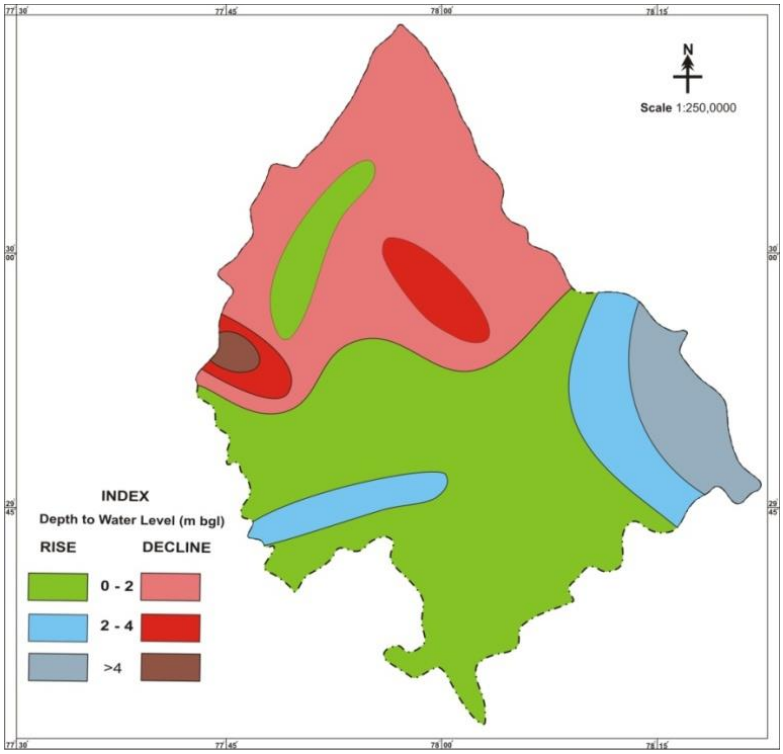


Figure 47 Water Level Fluctuation Map (May 2016 vs January 2017), Haridwar District

Visual interpretation of **Fig. 48** has shown that the minimum seasonal rise of 0-2 m is observed dominantly in northern, central and southern part of the Tarai zone and central and eastern part of Bhabar zone. Higher seasonal rise of 2-4 m is observed

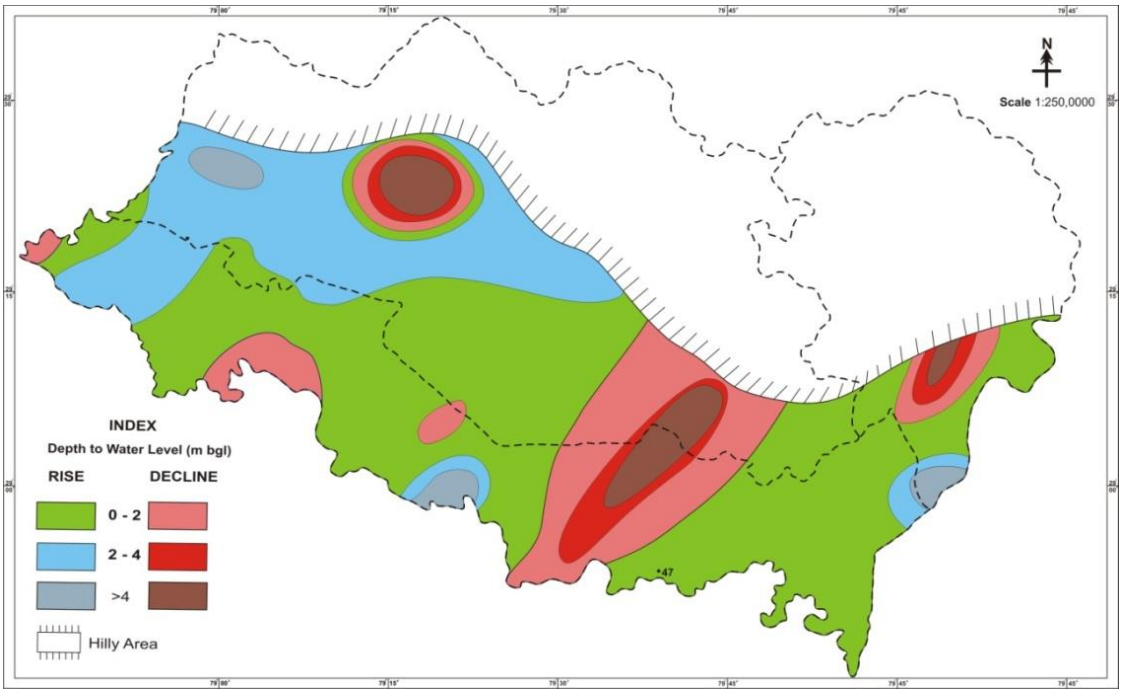


Figure 48 Water Level Fluctuation Map (May 2016 vs January 2017), US Nagar – Nainital - Champawat District

around Peeru Madara – Kaladhungi – Kathgodham (Nainital district) and Jaspur – Bharatpur (Udham Singh Nagar district). The highest seasonal rise of >4 m is observed at Bhagwanpur (Udham Singh Nagar district) and Banbasa (Champawat District). The minimum seasonal decline of 0-2 m is observed as outlier to the 2-4m seasonal decline zone and as isolated patch at Sultanpur Patti and Mahabir Nagar in Udham Singh Nagar district. Seasonal decline of 2-4m is observed as outlier to the seasonal decline zone of >4m, which is observed at Kichha (Udham Singh Nagar district), around Dhoniya, Khatbass (Nainital district) and around Bastia in Champawat District.

Table 22. Seasonal Water Level Fluctuation (May 2016 versus January 2017)

District	*No. of stations analyzed*	*Fluctuation (m)*				*Rise (m)*						*Decline (m)*					
		Rise		*Decline*		*0-2*		*2-4*		*>4*		*0-2*		*2-4*		*>4*	
		Min	*Max*	*Min*	*Max*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Dehradun	19	0.40	19.37	0.20	7.06	6	31.58	6	31.58	2	10.53	3	15.79	0	0.00	2	10.53
Haridwar	24	0.13	7.65	0.26	8.04	14	58.33	3	12.50	1	4.17	2	8.33	3	12.50	1	4.17
Udham Singh Nagar	26	0.18	5.12	0.07	2.39	16	61.54	3	11.54	1	3.85	5	19.23	1	3.85	0	0.00
Nainital	7	0.95	13.33	19.27	28.15	1	14.29	3	42.86	1	14.29	0	0.00	0	0.00	2	28.57
Champawat	2	--	6.25	--	9.05	0	0.00	0	0.00	1	50.00	0	0.00	0	0.00	1	50.00
Total	78	0.13	19.37	0.07	28.15	37	47.44	15	19.23	6	7.69	10	12.82	4	5.13	6	7.69

CHAPTER – 6

HYDROCHEMISTRY

Monitoring of groundwater quality is very important as this determines the suitability of groundwater for various purposes like domestic, agricultural and industrial use and also for deciphering the water quality trends in space and time. Analysis of hydrochemical data also helps in evaluating the nature and extent of groundwater pollution and to ascertain the effectiveness of pollution control measures already in existence.

The chemical quality of groundwater in Uttarakhand State has been ascertained from complete chemical analysis of one hundred and seventy-two (172) water samples collected during pre-monsoon period (May 2015). The analysis was carried out in Chemical Laboratory, North Region, Luckhnow. The result of chemical analysis for four parameters viz. Electrical Conductivity (EC), chloride (Cl), nitrate (NO_3) and fluoride (F) has been used to prepare thematic maps. The water samples were collected from ground water monitoring stations like dug wells, hand pumps and springs in Dehradun, Haridwar, Pauri Garhwal, Udham Singh Nagar, Nainital, Almora, Champawat and Uttarkashi districts. The result of chemical analysis is given in ***Table 23***.

6.1 Analytical Results and Discussions

The chemical quality of groundwater of shallow and deep aquifers in Uttarakhand State varies widely depending on physiography, soil texture and geology of the area. The aquifers are mostly dominated by Ca-Mg-HCO_3 and Ca-HCO_3 types of groundwater. The general chemical quality reveals that most of the wells contain low dissolved mineral contents and hence, groundwater in Uttarakhand state is fresh and potable. The chemical quality of groundwater with respect to Electrical Conductivity (EC), chloride (Cl), nitrate (NO_3) and fluoride (F) are given separately.

Table 23. Chemical Analysis of Water Samples Collected from Ground Water Monitoring Stations, Pre-monsoon (May 2016)

Sl.No.	Location	pH	E.C. (m/cm) at 25°C	Concentration (mg/l)											
				CO_3	HCO_3	Cl	F	NO_3	SO_4	TH as $CaCO_3$	Ca	Mg	Na	K	SiO_2
District: Dehradun															
1	Jhajra	7.92	370	nil	183	14	0.08	3.1	4.3	150	48	7.3	8.5	0.8	30
2	Majra	7.86	900	nil	317	14	0.09	16	146	400	92	41	14	0.8	28
3	Tarla Nagal	8.16	500	nil	256	14	0.08	nd	8.6	230	36	34	3.4	1.2	17
4	Nanda Ki Chowki	8.03	410	nil	159	36	0.08	1.8	6.7	160	44	12	16	0.8	17
5	Selaqui	7.42	280	nil	85	21	0.01	19	17	100	16	15	13	0.8	39
6	Badripur	7.67	360	nil	183	7.1	0.09	0.6	9.6	140	48	4.9	11	0.8	35
7	Badonwala	7.86	670	nil	293	21	0.03	16	38	300	72	29	8.5	0.8	29
8	Kuanwala	8.03	270	nil	134	7.1	0.08	nd	5	110	24	12	6.9	1.5	19
9	Rishikesh	7.98	400	nil	159	14	0.13	5	37	170	40	17	6.9	1.2	23
10	Purkulgaon	7.81	450	nil	110	14	0.12	3.1	103	200	56	15	7.4	0.8	23
11	Maldevta	8.57	2350	12	159	92	0.53	0.2	816	170	12	34	448	9.7	8
12	Gularghati	8.04	860	nil	207	14	0.2	0.37	221	400	92	41	3.2	1.2	16
13	Khandgaon	7.89	530	nil	220	28	0.16	nd	29	180	36	22	35	1.5	14
14	Lal Tappar	7.81	220	nil	85	21	0.06	0.24	5.8	90	16	12	5.5	1.2	8
15	Kotimaichak	7.50	235	nil	110	7.1	0.19	1.9	6.7	90	20	9.7	9.9	0.8	17
16	Soda Sarauli	7.89	350	nil	122	14	0.11	3.1	46	140	40	9.7	12	1.2	24
17	Bhaniawala	8.06	600	nil	171	14	0.11	1.2	125	270	56	32	4.6	1.2	15
18	Sahaspur	7.69	240	nil	85	28	0.1	0.3	2.4	80	16	9.7	15	0.8	14
19	Dakpathar	7.77	350	nil	146	14	0.16	9.3	20	140	40	9.7	14	1.2	22
20	Barotiwala	7.26	190	nil	73	14	0.07	5	5.7	70	12	9.7	9.2	0.4	32
21	Dhakrani	7.53	180	nil	61	14	0.06	0.6	14	70	20	4.9	5	0.8	21

22	Timli	7.56	250	nil	128	7.1	0.1	0.6	1.9	100	28	7.3	7.4	0.8	33
23	Barawala	7.61	185	nil	49	7.1	0.09	27	14	70	16	7.3	7.1	0.8	31
24	Baluwala	7.26	165	nil	79	7.1	0.09	2.5	2.4	50	12	4.9	13	0.4	39
25	Telpura	7.76	880	nil	354	28	0.03	28	77	400	92	41	7.8	0.8	26
26	Haripur	7.85	350	nil	146	14	0.08	13	18	140	44	7.3	9.7	1.9	24
27	Mothrowala	7.91	680	nil	281	14	nd	nd	72	310	64	36	9.4	0.8	17
28	Chandmari	7.99	720	nil	232	14	nd	3.1	134	340	72	39	3.7	1.2	17
29	Chhorba	8.18	170	nil	73	14	nd	nd	2.4	50	12	4.9	13	0.4	25
30	Khandari College	8.12	400	nil	171	21	0.12	1	19	150	24	22	19	1.5	22
31	Bhatta	8.28	630	nil	232	21	0.15	2.3	84	300	56	39	3	0.7	17
32	Khandoli	8.04	135	nil	61	7.1	nd	nd	2	50	4	9.7	5.5	0.3	37
33	Soda Sarauli	9.51	225	24	24	2.1	0.07	2	16	80	16	10	11	0.5	29
District: Haridwar															
34	Budhwa Shahid	8.00	505	nil	305	7.1	nd	18	7.1	260	72	19.5	8.5	1.4	22
35	Shahidwala Grant	7.90	581	nil	329	7.1	nd	34	6	300	76	26.8	8.3	1.3	20
36	Buggawala	8.10	564	nil	342	7.1	nd	23	5.4	290	76	24.3	9.2	1.4	22
37	Bandarjud	8.00	592	nil	366	14	nd	5.5	2.5	295	64	32.8	14	1.6	24
38	Rathaura	7.80	570	nil	354	7.1	nd	0.25	2.8	230	32	36.5	35	2.7	25
39	Kota Muradpur	8.00	628	nil	403	7.1	nd	0.18	3.2	260	56	29.2	39	2.4	26
40	Teliwala	7.90	902	nil	317	92	nd	33	71	360	108	21.9	63	2.9	15
41	Imlikhera	8.10	564	nil	354	7.1	0.12	1.4	6.3	135	28	15.8	80	1.9	18
42	Bahabalpur	8.00	559	nil	354	11	0.08	1.8	2.7	245	48	30.4	29	1.8	20
43	Bhagwanpur	8.10	812	nil	329	96	0.12	0.81	37	350	72	41.3	44	3.6	21
44	Chudiyala	7.69	620	nil	378	14	0.36	nd	10	275	56	32.832	29	3.2	25
45	Iqbalpur	7.97	455	nil	262	18	0.52	nd	9.1	200	44	22	20	4.6	26
46	Jhabrera	7.75	950	nil	354	78	0.33	26	80	360	68	46	70	8.4	25
47	Chudiyala	8.03	420	nil	250	3.5	0.22	0.09	13	180	44	17	14	3.8	26

48	Khera Jat	8.15	455	nil	244	11	0.14	5.1	25	230	52	24	8.1	3.8	30
49	Gurkul Narsan	8.15	545	nil	281	25	0.2	nd	36	280	60	32	7.5	4.3	26
50	Libraheri	7.75	1535	nil	494	128	0.13	86	177	490	64	80	80	119	28
51	Manglore	7.86	544	nil	299	11	0.21	1.3	37	270	68	24	6.9	5.9	22
52	Landhaura	7.75	550	nil	329	7.1	0.11	7.7	13	250	64	22	23	3.2	32
53	Sikhar	8.10	655	nil	378	14	0.04	23	11	315	76	30	19	2.5	32
54	Amkheri	8.15	397	nil	220	11	0.3	11	7.8	180	48	15	11	2.8	28
55	Mundlana	7.88	665	nil	329	35	0.13	29	23	290	76	24	31	4	31
56	Hussainpur	8.20	465	nil	287	11	0.03	0.08	4.3	185	36	23	30	5	24
57	Laksar	7.70	1500	nil	390	128	nd	3.8	310	610	88	95	92	11	14
58	Goverdhanpur	7.90	725	nil	427	21	0.01	0.31	17	200	44	22	87	5.1	20
59	Khanpur	8.20	630	nil	366	21	0.19	nd	18	180	40	19	74	7	19
60	Dallawala	8.05	800	nil	403	43	0.1	0.94	45	230	60	19	88	8.1	20
61	Roorkee	8.16	332	nil	171	7.1	0.44	nd	22	155	40	13	8.2	2.9	19
62	Bahadrabad	8.00	262	nil	128	7.1	0.21	nd	20	120	36	7.3	5.3	0.49	20
63	Sarai	7.66	756	nil	342	35	0.17	31	43	230	60	19	35	72	17
64	Panjaheri	8.18	505	nil	256	21	0.14	9.5	23	235	68	16	17	4.8	12
65	Dhanpura	8.04	588	nil	256	28	0.13	36	44	270	52	34	22	4.8	20
66	Shpur Sitlakhera	7.98	730	nil	342	28	0.21	41	42	310	68	34	19	36	20
67	Bikkhampur	7.76	585	nil	317	14	0.23	0.18	30	280	60	32	17	4.3	23
68	Bhogpur	8.19	940	nil	427	43	0.23	25	67	315	84	26	39	91	22
69	Sultanpur	7.70	1095	nil	415	85	nd	49	82	435	92	50	62	20	23
70	Dudha Dayalwala	7.84	537	nil	281	14	0.05	0.1	34	225	56	21	22	2.2	24
71	Laldhang	7.85	572	nil	305	7.1	nd	8.3	35	280	88	15	15	1.5	17
72	Shyampur	7.86	598	nil	336	14	0.01	15	21	295	72	28	8.7	3.4	19
72	Bhupatwala	8.10	555	nil	329	14	0.08	1.7	12	260	72	19	21	2.1	22

District: Pauri Garhwal															
73	Kotdwar	8.20	560	nil	305	14	0.22	2.47	13	230	48	27	25	2.39	29
District: Uttarkashi															
74	Chiniyalisaur	8.01	835	nil	305	64	0.14	41	29	280	72	24	57	7	27
75	Devidhar	8.21	320	nil	159	14	0.13	0.6	2.6	125	24	16	11	0.7	18
76	Uttarakashi	7.96	425	nil	159	36	0.07	13	14	160	40	15	17	5.5	27
77	Barkot	7.94	180	nil	73	14	nd	nd	2	70	16	7.3	6	0.6	18
78	Sharukhet	8.12	290	nil	122	21	0.01	nd	4.6	100	20	12	15	1.3	16
79	Ganeshpur	7.92	120	nil	37	11	nd	nd	7.6	50	16	2.4	0.4	3.1	16
80	Maneri	7.86	350	nil	98	50	0.14	nd	17	70	8	12	41	3.4	19
81	Dharasu	8.26	500	nil	268	7.1	0.09	0.8	6.36	180	64	4.9	20	15	27
82	Nagal	8.08	225	nil	85	21	nd	nd	6	100	20	12	3	0.3	22
83	Rotori Sar	8.03	230	nil	92	14	0.01	7.2	8.5	100	28	7.3	3	2	27
District: Udham Singh Nagar															
84	Angadpur	8.03	400	nil	244	7.1	0.35	0.26	4.7	180	56	9.7	12	0.92	35
85	Patrampur	7.96	520	nil	317	14	0.68	0.09	1.8	180	32	24	41	0.89	29
86	Jaspur	8.30	650	nil	403	7.1	1.4	0.38	3.9	90	20	9.7	113	1.06	23
87	Durgapur	8.25	500	nil	293	7.1	0.43	0.06	5.8	200	52	17	27	1.34	29
88	Bharatpur	8.27	570	nil	342	7.1	0.93	0.28	4.2	120	24	15	77	1.53	23
89	Missarwala	8.19	500	nil	293	7.1	0.27	1.46	8.9	200	64	9.7	27	1.7	31
90	Barkhera Pandey	8.06	450	nil	256	7.1	0.36	nd	11	170	28	24	31	1.87	30
91	Kashipur	7.80	750	nil	342	43	0.25	0.68	43	230	44	29	63	2.57	29
92	Sultanpur Patti	8.15	369	nil	207	7.1	0.14	nd	nd	160	36	17	9.5	1.38	26
93	Kanaura	8.18	597	nil	342	14	0.32	2.31	nd	260	56	29	15	1.56	31
94	Jhagarpuri	8.24	620	nil	317	7.1	0.32	0.02	54	260	36	41	27	1.95	30
95	Patharpur	8.07	699	nil	354	21	0.25	0.28	9	310	44	49	11	8.72	21

96	Badakheda	7.90	684	nil	366	7.1	0.21	1.54	20	310	56	41	15	2.05	30
97	Mahabir Nagar	8.20	490	nil	195	7.1	0.13	3.92	65	230	20	44	7.2	1.71	30
98	Lalpuri	8.20	510	nil	293	7.1	0.1	3.68	8	230	48	27	8.5	1.71	32
99	Kopa Signal	8.20	510	nil	293	14	0.21	0.47	2	240	36	36	5.9	2.19	27
100	Beria Daulat	7.80	661	nil	293	50	0.21	0.26	22	290	36	49	25	2.27	31
101	Badripur	8.14	740	nil	390	14	0.21	0.12	26	320	40	54	29	3.26	24
102	Pritampur Fauji Colony	7.90	627	nil	354	7.1	0.21	0.12	20	270	52	34	17	1.6	31
103	Jogipur	7.80	6.2	nil	366	14	0.27	nd	1	270	40	41	16	1.53	30
104	Bannakhera	7.90	650	nil	390	7.1	0.18	0.02	5	290	48	41	16	1.5	30
105	Bazpur	7.80	725	nil	366	21	0.25	0.11	50	280	52	36	40	1.54	33
106	Jharkhandi	7.70	680	nil	390	7.1	0.16	9.8	14	320	48	49	8.9	1.24	30
107	Barhani	7.80	650	nil	305	14	0.19	0.21	69	280	28	51	24	1.18	28
108	Sankhera	8.14	399	nil	207	7.1	0.17	2.3	2	170	32	22	9.6	1.23	30
109	Bhagwanpur	8.00	350	nil	207	7.1	0.26	nd	5	150	32	17	12	2.38	31
110	Patthar Chatta	7.90	413	nil	232	7.1	0.20	5.2	17	190	40	22	8.9	2.89	34
111	Santipur	8.10	343	nil	183	7.1	0.24	0.13	15	150	48	7.3	7.4	2.33	26
112	Rajpura	8.10	370	nil	195	7.1	0.49	0.73	20	150	44	9.7	15	1.41	31
113	Sitarganj	7.90	450	nil	268	7.1	0.28	nd	8	170	48	12	26	1.84	31
114	Kalyanpur	8.00	360	nil	207	7.1	0.20	nd	7.7	130	32	12	27	1.89	31
115	Begur Mod	8.00	450	nil	268	7.1	0.48	nd	15	160	40	15	34	1.16	28
116	Bara	8.20	450	nil	256	7.1	0.38	0.07	20	170	40	17	31	1.65	29
117	Pipiliya Chauraha	8.10	501	nil	220	7.1	0.42	0.71	55	230	52	24	12	1.66	32
118	Kiccha	8.15	343	nil	183	7.1	0.46	0.34	23	140	40	9.7	16	1.63	30
119	Bidora	7.97	371	nil	220	7.1	0.20	nd	8	150	44	9.7	19	1.58	30
120	Nanak Mata	7.84	700	nil	366	21	0.64	1.8	28	240	44	32	41	13.82	25
121	Tukri	7.90	414	nil	220	7.1	0.29	0.57	nd	160	44	12	17	1.17	27

122	Dhayanpur	7.90	398	nil	244	7.1	0.20	nd	0.5	170	44	15	14	1.44	29
123	Khatima	8.10	510	nil	317	7.1	0.39	1.27	nd	200	44	22	29	2.8	32
124	Chakarpur	7.70	399	nil	220	7.1	0.22	0.39	nd	160	56	4.9	9.3	2.22	25
125	Majhola	7.60	430	nil	256	7.1	0.19	0.29	nd	190	60	9.7	9.6	2.3	21
126	Barinjariya	8.10	350	nil	207	7.1	0.35	nd	nd	160	44	12	8.3	2.61	27
127	Sara Sariya	8.10	750	nil	403	7.1	0.64	0.13	30	220	40	29	77	1.13	25
128	Gangapur	8.20	400	nil	232	7.1	0.21	6.56	2	180	48	15	9.2	2.64	34
129	Kanakpur	8.20	410	nil	232	7.1	0.2	8.36	2.2	180	56	9.7	8.4	2.71	35
130	Kamariaya Pakki	8.20	354	nil	183	7.1	0.3	3.2	23	150	40	12	15	2.24	32
131	Rudrapur	8.10	360	nil	183	7.1	0.3	4.54	24	150	36	15	16	2.27	33
132	Dhanauri Patti	8.10	685	nil	256	85	0.4	0.68	23	260	52	32	39	1.96	28
District Nainital															
133	Bhelparao	8.00	632	nd	354	14	0.04	2.4	35	330	64	41.3	8.2	1.5	22
134	Dhela	7.80	523	nd	305	11	nd	14	11	265	84	13.4	11	1.5	15
135	Peeru Madara	7.90	458	nd	268	14	nd	7.6	6.6	230	60	19.5	9.5	1.6	22
136	Dhoniya	7.90	543	nd	232	7.1	nd	6.8	86	285	60	32.8	5.5	1.1	17
137	Lamchaur	8.00	302	nd	171	7.1	nd	0.21	16	150	32	17	6.9	1	14
138	Kaladungi	8.10	661	nd	329	14	nd	4.2	65	350	64	46.2	5.8	1.3	18
139	Kathgodam	8.10	553	nd	293	21	nd	19	19	255	68	20.7	21	4.7	18
140	Khat Baas (Pachuakhera)	8.00	473	nd	281	7.1	nd	9	9.2	240	76	12.2	8	1.2	18
141	Dogaon	7.90	412	nd	256	7.1	nd	1.1	5.8	200	56	14.6	11	1.6	15
142	Garam Pani	8.00	175	nd	92	11	nd	1.22	3.3	90	20	9.7	1.8	0.69	12
143	Salari	7.90	356	nd	183	14	0.02	10	12	180	44	17	6.5	1.5	28
144	Kudagath	7.80	498	nd	256	14	nd	5.6	38	270	36	43.8	1.4	0.84	6.7
145	Jeyolikote	8.00	279	nd	146	7.1	nd	6.2	12	130	32	12.2	8.2	2.8	13
146	Sitapur	7.90	324	nd	171	14	0.13	0.26	15	160	36	17	8.1	1	19
147	Ranibagh	8.00	573	nd	262	32	nd	44	18	270	80	17	20	3.3	19

District Almora															
148	Patli Malla	8.00	291	nd	153	14	nd	4.3	13	140	44	7.3	8.9	1.8	19
149	Katarmal	7.90	252	nd	67	32	nd	22	17	100	32	7.9	14	5	35
150	Dharanaula	7.90	570	nd	98	64	nd	110	43	160	52	7.3	62	12	29
151	Palna	8.00	154	nd	73	7.1	0.09	0.88	6.9	60	12	7.3	8.1	2.1	31
152	Chinoda	7.90	192	nd	98	14	nd	0.26	3.7	100	24	9.7	2.7	0.53	16
153	Guruda-II	8.00	63	nd	24	7.1	0.05	0.31	3.3	30	8	2.4	0.09	2	10
154	Someshwar	8.00	92	nd	49	5.3	nd	0.16	3	50	16	2.4	0.34	0.1	12
155	Bachuradi	7.80	691	nd	366	28	nd	38	12.1	340	56	48.6	9.5	17	15
156	Bhagtola	7.90	159	nd	85	7.1	nd	0.94	4.5	65	24	1.2	8.9	0.6	23
157	Itola	7.90	162	nd	73	14	nd	3.5	4.1	70	16	7.3	8.1	1.1	26
158	Channi Bartola	7.90	99	nd	43	11	nd	0.49	3.1	50	12	4.9	1.5	1.1	12
159	Dhalangaon	7.90	476	nd	256	21	1.64	2.1	14	180	36	21.9	32	10	13
160	Semalkhet	8.00	335	nd	201	7.1	nd	7.6	5.5	180	40	19.5	1.3	1.7	9.2
161	Naula	7.90	209	nd	122	7.1	nd	0.43	5.6	105	24	10.9	4.2	1.3	13
166	Baniya Diggi	7.80	215	nd	104	14	nd	6.9	8	85	28	3.6	14	2.5	25
167	Jholi	7.90	115	nd	37	12	nd	4.9	8.1	40	12	2.4	8.2	1.9	26
168	Dhansari	7.80	367	nd	232	7.1	0.03	0.71	4.6	200	40	24.3	0.43	0.8	10
169	Dhansari-II	7.95	365	nd	220	11	nd	1.18	4.5	200	40	24.3	0.4	0.68	9.7
170	Gurna	7.90	460	nd	281	11	nd	0.74	6	250	44	34	0.5	1	11
171	Dharanaulla Zoo	8.00	124	nd	55	7.1	nd	3.3	5.8	40	8	4.9	11	1.9	39
172	Peepla Dhar	7.90	368	nd	220	11	nd	0.63	3.7	200	36	26.8	0.31	0.53	11

6.1.1 Electrical Conductivity (EC)

The Electrical Conductivity (EC) of groundwater is a measure of the degree of mineralization in it. During pre-monsoon, 2015 the EC value was observed to vary from a minimum of 135 µS/cm (at 25°C) at Khandoli spring in Dehradun district to a maximum of 2350 µS/cm at maldeota also in dehradun district. The frequency distribution of Electrical Conductivity in Uttarakhand is given in **Table 24.**

Table 24. Frequency distribution of Electrical Conductivity (May 2015)

Electrical Conductivity (µS/cm at 25°C)	0 – 250	>250 – 750	>750 – 2250	>2250
No. of Samples	27	128	13	1
% of Total No.	16	74	8	1

A study of the above table indicates that majority of the samples (128 out of 172 samples or 74%) have shown EC in the range of >250–750 µS/cm. Low EC value of 0–250 µS/cm was found in 27 ground water samples, which is 16% of the total number of samples. Only 13 samples out of 172 (8% of the total number) have shown higher EC value of >750–2250 µS/cm. The analysis results also indicate that during pre-monsoon 2015, only 1 sample has shown EC higher than 2250 µS/cm in Uttarakhand State.

A map showing the spatial distribution of chloride concentration in Dehradun and Haridwar section of Uttarakhand State is given in ***Fig. 49 and Fig 50*** respectively while another map showing the spatial variation in distribution of chloride concentration in Udham Singh Nagar-Nainital section is shown in ***Fig. 51.***

A perusal of these maps indicates that relatively high EC (>2350 µS/cm) is observed only in a small zone in the eastern part of Dehradun district. The EC value between 750 to 2350 µS/cm is observed as small isolated patches around Gularghati and Majra in Dehradun district; around Teliwala, Bhagwanpur, Jhabrera, Laksar, Dallawala and Sultanpur in Haridwar district. Rest of the areas in all the three sections had shown the low EC values in groundwater samples collected during pre-monsoon, 2015.

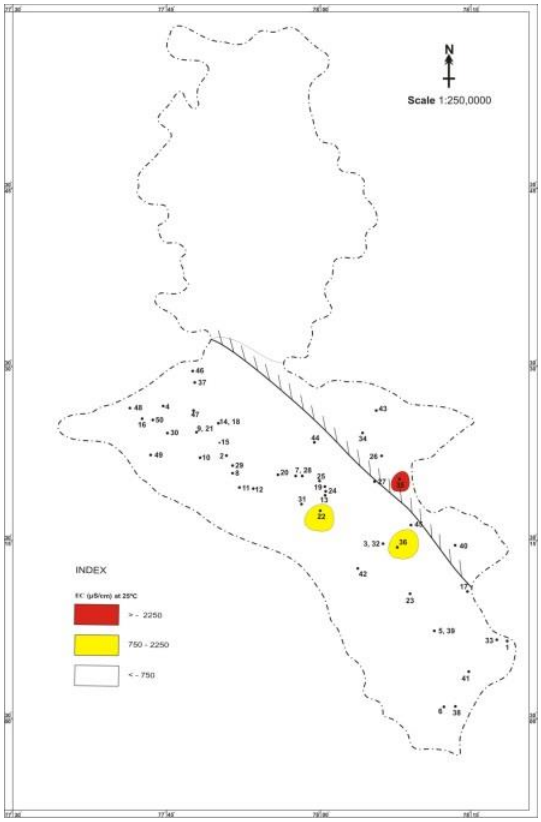


Figure 49 EC Map of Dehradun District

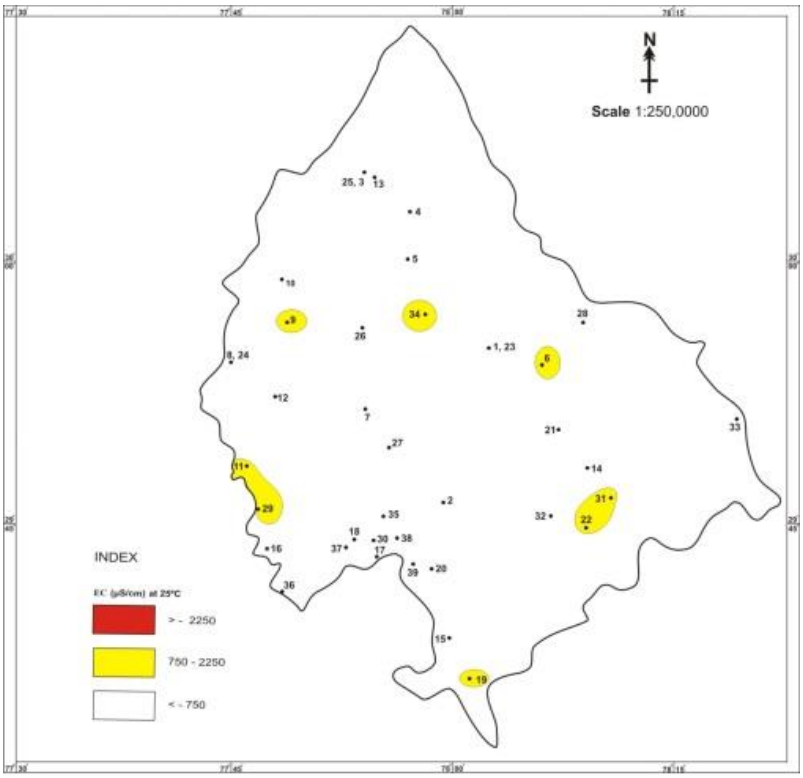


Figure 50 EC Map of Haridwar District

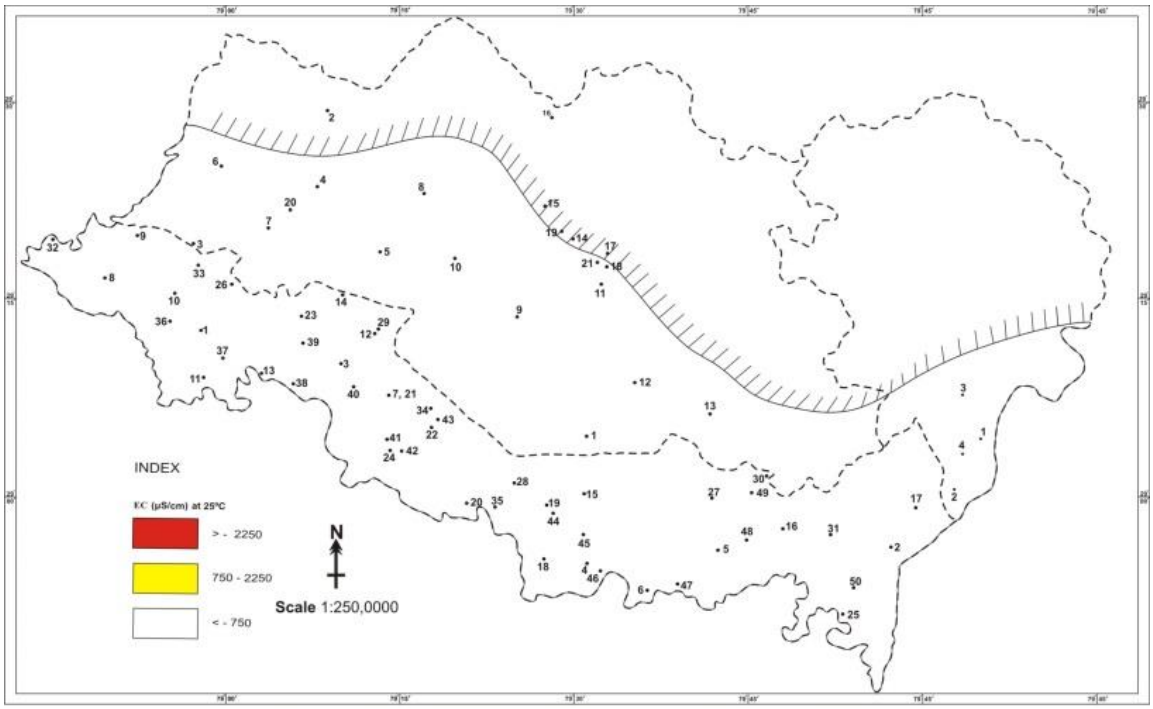


Figure 51 EC Map of Udham Singh Nagar, Nainital and Champawat District

6.1.2 Chloride:

The analysis result of one hundred and seventy two (172) ground water samples collected in pre-monsoon 2015 indicates that the highest chloride concentration is observed at Librahedi and Laksar (128 mg/L), in Haridwar district. The frequency distribution of chloride concentration in ground water of Uttarakhand State is given in ***Table 25.*** As 3 no of groundwater samples have shown Chloride below the detection limit (viz. nil concentration), hence the sample no's used for classification is 169 samples.

Table 25. Frequency distribution of Chloride concentration (May 2015)

Chloride (mg/L)	0-50	>50-100	>100-150	>150
No. of Samples	159	8	2	0
% of Total No.	94	5	1	0

A study of the above table indicates that majority of samples (159 out of 169 samples or 94%) have shown chloride concentration in the range of 0–50 mg/L; whereas only eight samples (5% of total number) have shown chloride concentration in the range of >50–100 mg/L. It is also observed that only two sample (1% of total) has shown relatively high chloride concentration in the range >100–150 mg/L whereas no sample has shown the highest chloride concentration of >150 mg/L in Uttarakhand State during pre-monsoon 2015. Hence, it can be stated that groundwater is predominantly fresh and potable during pre-monsoon 2015.

A map showing the spatial distribution of chloride concentration in Dehradun and Haridwar section of Uttarakhand State is given in ***Fig. 52 and Fig 53*** respectively while another map showing the spatial variation in distribution of chloride concentration in Udham Singh Nagar-Nainital section is shown in ***Fig. 54.***

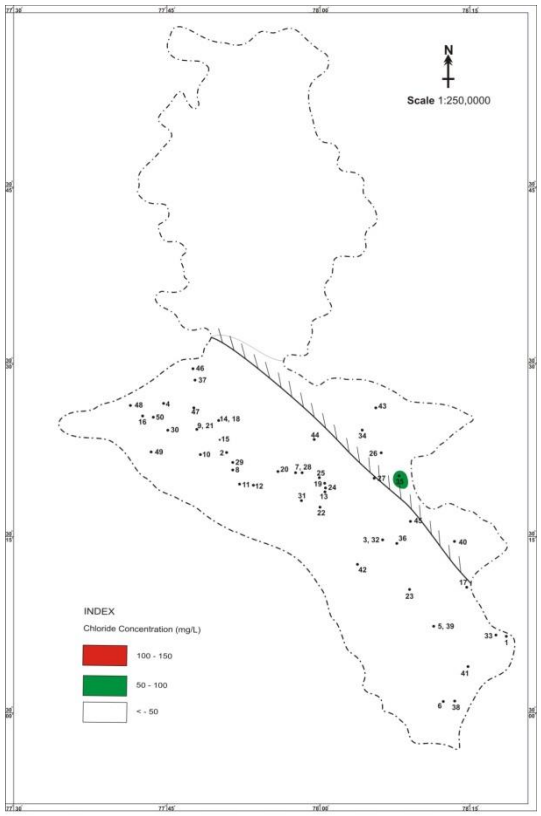


Figure 52 Chloride Map of Dehradun District

A perusal of the figures reveals that very low chloride concentration (0-50 mg/l) in groundwater is observed dominately in all the three sections i.e Dehradun, Haridwar and Udham singh nagar- Nanital section. Relatively high chloride concentration (>50 mg/L) is observed as isolated patches around Maldeota in Dehradun section; around Bhagwanpur, Jhabrera, Sultanpur in Haridwar district. And also as small patch around Dhanauri Patti in Udham Singh Nagar district falling in the Tarai zone. The Highest chloride concentration (100-150 mg/l) is observed only around Librahedi and Laksar in Haridwar district. None of the areas in all the 3 sections has shown chloride value >150 mg /l.

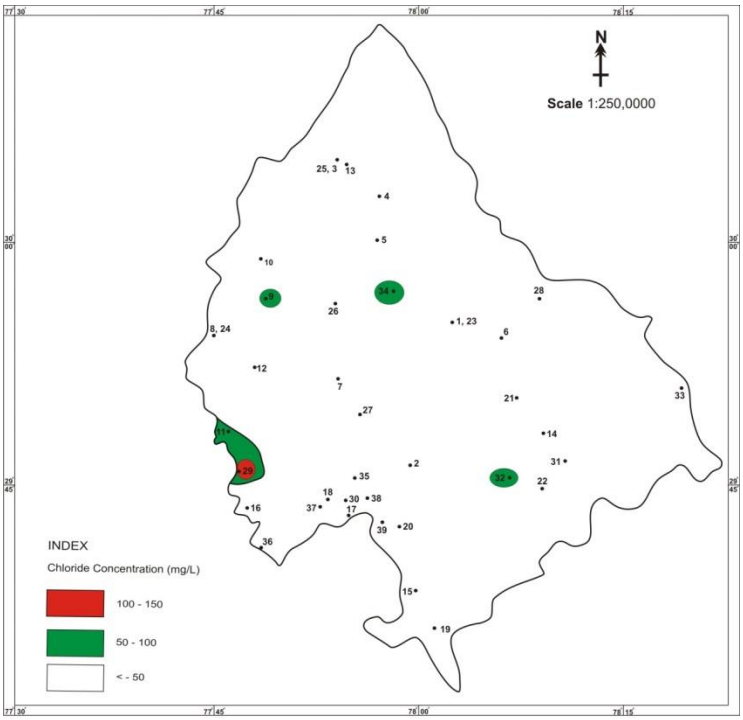


Figure 53 Chloride Map of Haridwar District

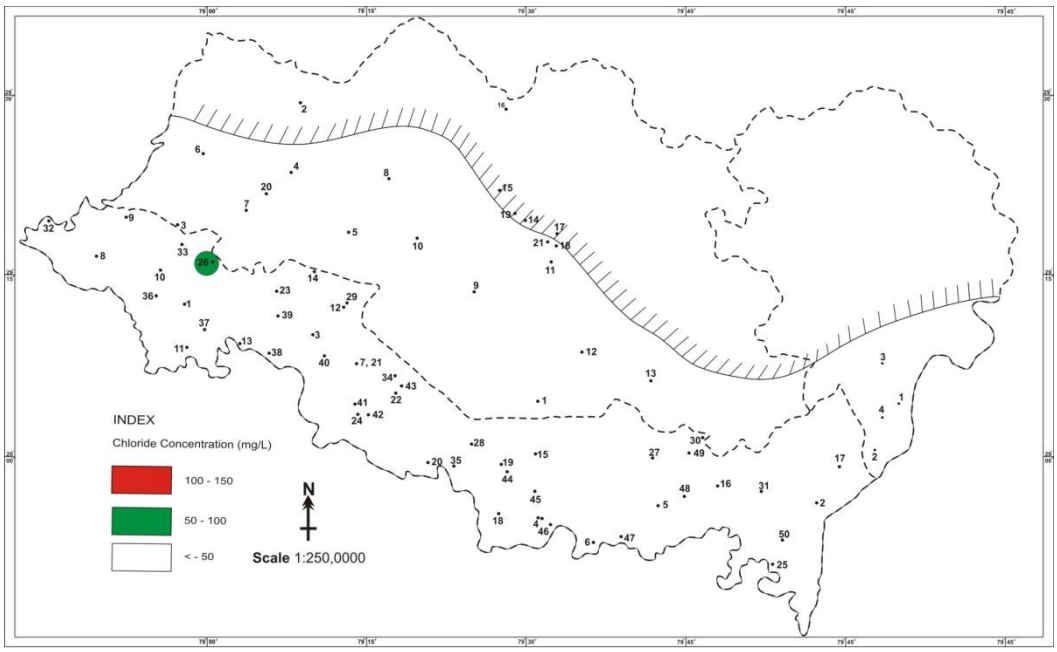


Figure 54 Chloride Map of Udham SIngh NAgar, Nainital and Champawat District

6.1.3 Nitrate

Concentration of nitrate in groundwater in Uttarakhand State during pre-monsoon 2015 is found to be highly variable. Out of 172 samples, 49 samples collected from ground water monitoring stations have shown nil value of nitrate. This indicates that the problem of nitrate contamination in ground water of Uttarakhand State is minimal. The minimum nitrate concentration of 0.01 mg/L is observed at Jhagarpuri and Bannakhera in Udham Singh Nagar district, whereas the maximum concentration of 110 mg/L is recorded in a spring at Dharnaula, Almora district. The frequency distribution of nitrate concentration in ground water in Uttarakhand State is given in ***Table 26.*** As 30 groundwater samples have shown nitrate below the detection limit (viz. nil concentration), hence the sample no's used for classification is 142 samples.

Table 26. Frequency distribution of Nitrate concentration (May 2015)

Nitrate (mg/L)	<45	45–100	>100
No. of Samples	140	1	1
% of Total No.	98	1	1

A perusal of the above table indicates that majority of samples (140 out of 142 or 98% of total samples) are suitable for drinking purpose as the nitrate concentration in these samples is below the Acceptable Limit of 45 mg/L (BIS, IS 10500, 2009). Higher nitrate concentration of 45–100 mg/L is found only in 1 sample (1% of total) viz. at Sultanpur in Haridwar district. Nitrate above 100 mg/L is also recorded at 1 location viz. at Dharnaula (110 mg/L) in Almora district.

A map showing the spatial distribution of chloride concentration in Dehradun and Haridwar section of Uttarakhand State is given in ***Fig. 55 and Fig 56*** respectively while another map showing the spatial variation in distribution of chloride concentration in Udham Singh Nagar-Nainital section is shown in ***Fig. 57.***

Visual interpretation of ***Fig. 55 & 57*** indicated that no area in Dehradun, Udham singh nagar-Nanital section has shown Nitrate concentration higher than the Acceptable Limit of 45 mg/L. On the other hand, visual interpretation of ***Fig. 56*** indicates that high Nitrate concentration (>45 mg/L) is found in and around Sultanpur in the southeastern part of Haridwar district.

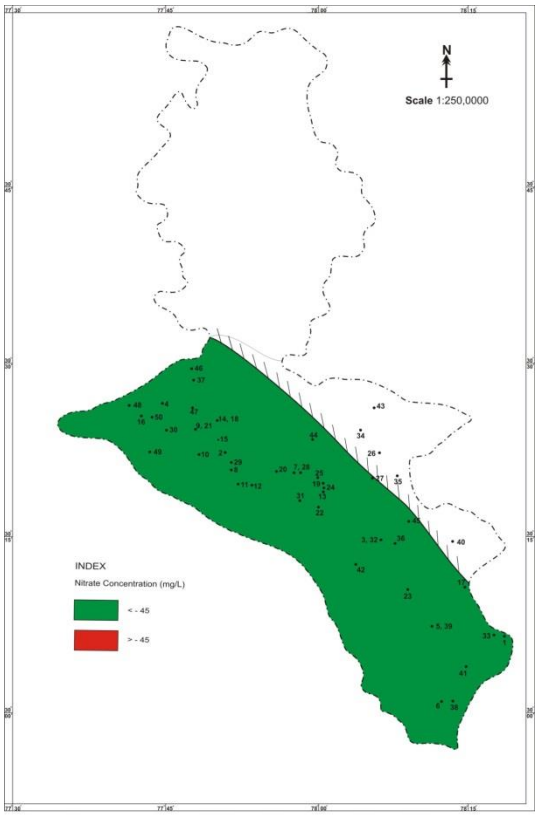


Figure 55 Nitrate Map of Dehradun District

The high nitrate concentration in groundwater is anthropogenic and probably caused by disposal of solid/liquid waste and effect of sewerage in and around the source. The single sample in which high nitrate was collected from unconfined aquifer, which is limited in aerial extent. Overall, the nitrate concentration in the groundwater monitoring stations in Uttarakhand indicates that groundwater is suitable for drinking purpose.

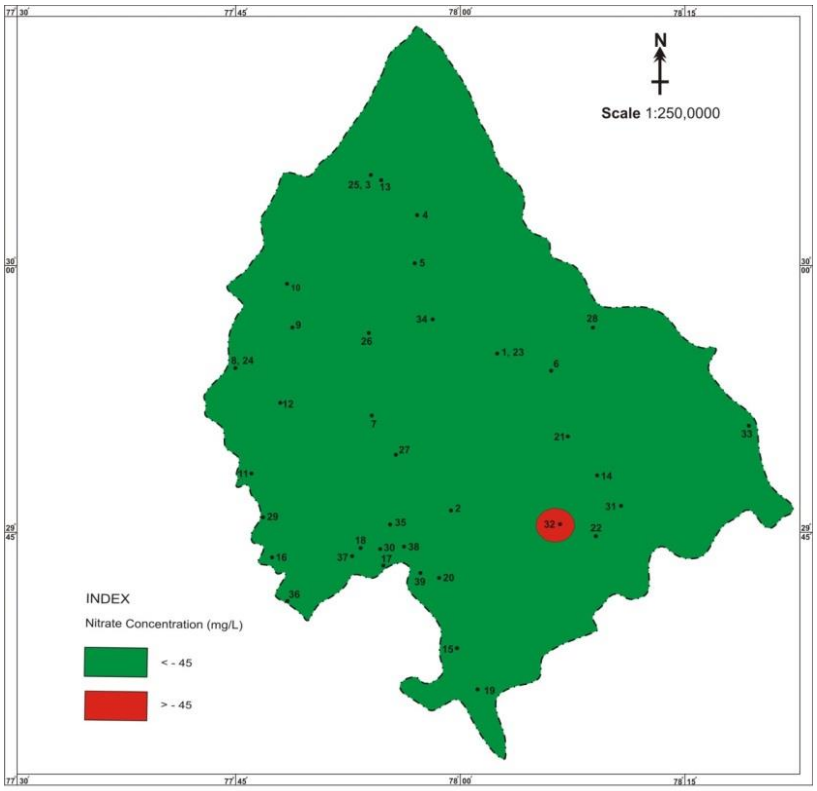


Figure 56 Nitrate Map of Haridwar District

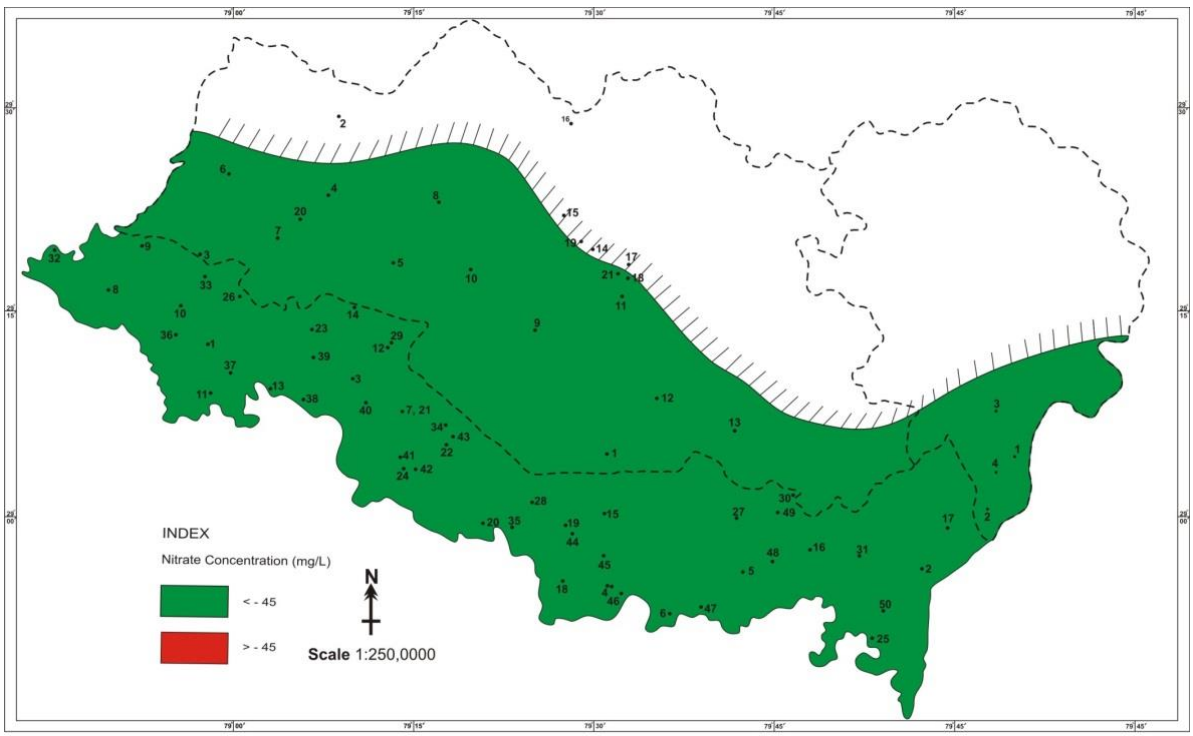


Figure 57 Nitrate Map of Udham Singh Nagar, Nainital and Champawat District

6.1.4 Fluoride

Out of 172 ground water samples for which fluoride concentration is available (pre-monsoon, 2015) the highest concentration was 1.64 mg/L at Dhalangaon in Almora district. The minimum concentration of fluoride in ground water during pre-monsoon 2015 is 0.03 mg/L in a hand pump at Selaqui (Dehradun district); Goverdhanpur & Shyampur (Haridwar District) and at Sharukhet (Uttarkashi district). The frequency distribution of fluoride concentration in groundwater in Uttarakhand State during pre-monsoon, 2015 is given in ***Table 27.*** As 49 no of groundwater samples have shown Flouride below the detection limit (viz. nil concentration), hence the sample no's used for classification is 123 samples

Table 27. Frequency distribution of Fluoride concentration (May 2015)

Fluoride (mg/L)	<1.0	1.0-1.5	>1.5
No. of Samples	121	1	1
% of Total No.	98	1	1

A perusal of the table indicates that majority of samples (121 out of 123 samples or 98% of total) are suitable for drinking purpose as fluoride concentration in them was below the Acceptable Limit of 1.0 mg/L (BIS, IS 10500, 2009). Higher fluoride concentration (higher than the Acceptable Limit but lower than the Permissible Limit) in the range of 1.0-1.5 mg/L is found only in one sample, which was 1% of the total samples. Fluoride higher than the Permissible Limit (>1.5 mg/L) is also found in only one ground water samples during pre-monsoon, 2015. However, this high value is possibly attributed to some local phenomenon and/or some anomalous rock-water interaction process.

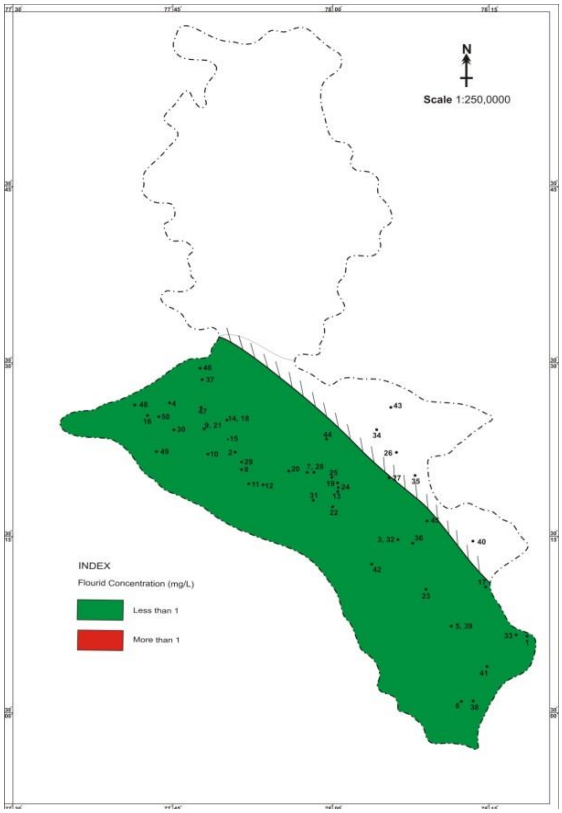


Figure 58 Flouride Map of Dehradun District

A map showing the spatial distribution of chloride concentration in Dehradun-Haridwar section of Uttarakhand State is given in ***Fig. 58 and Fig 59*** respectively while another map showing the spatial variation in distribution of chloride concentration in Udham Singh Nagar-Nainital section is shown in ***Fig. 60.***

Visual interpretation of ***Fig. 58 & 59*** indicated that no area in Dehradun-Haridwar section has shown fluoride concentration higher than the Acceptable Limit of 1.0 mg/L. On the other hand, visual interpretation of ***Fig. 60*** indicates that high fluoride concentration (>1.0 mg/L) is found in and around Jaspur in the western part of Udham Singh Nagar district.

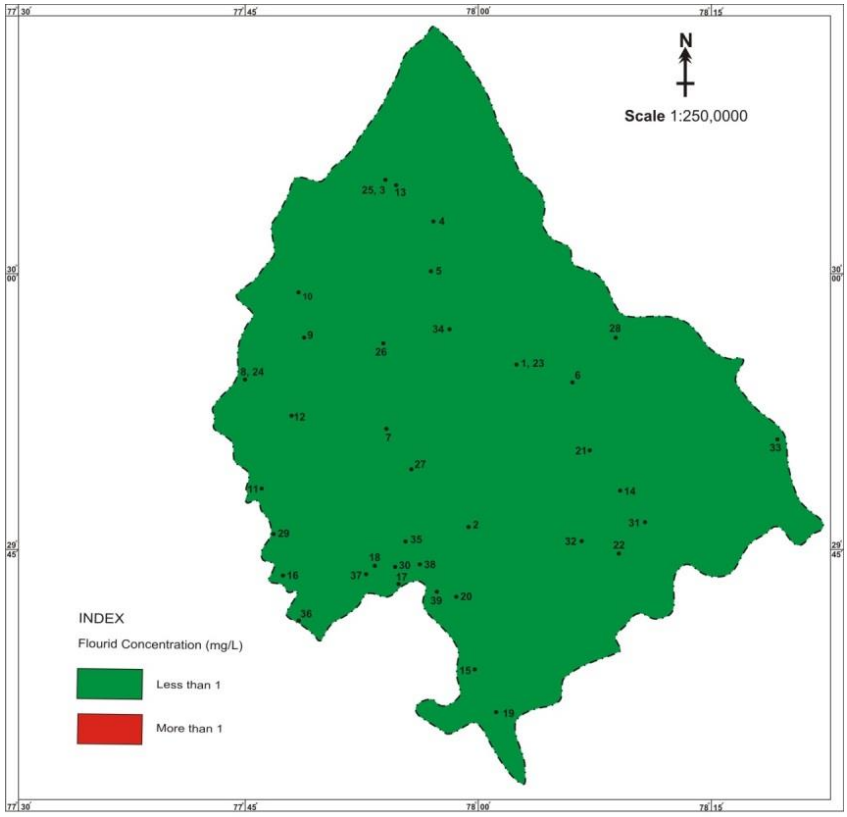


Figure 59 Flouride Map of Haridwar District

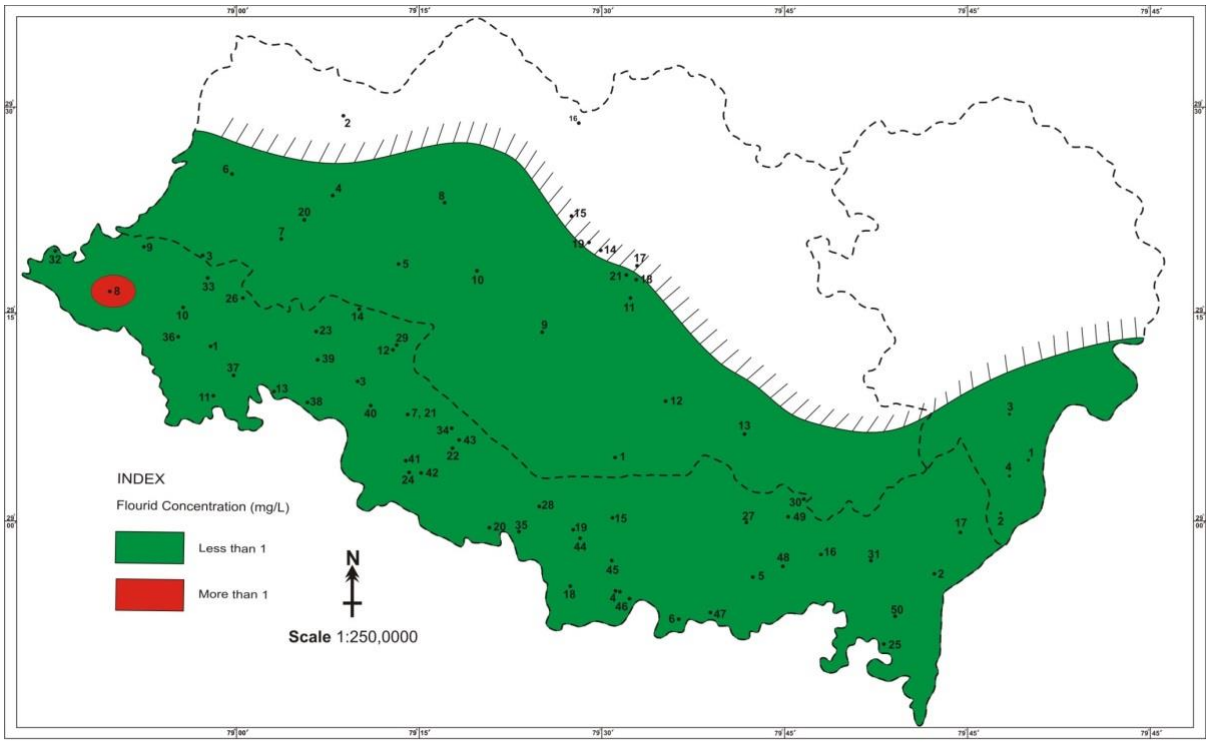


Figure 60 Flouride Map of Udham Singh Nagar, Nainital and Champawat District