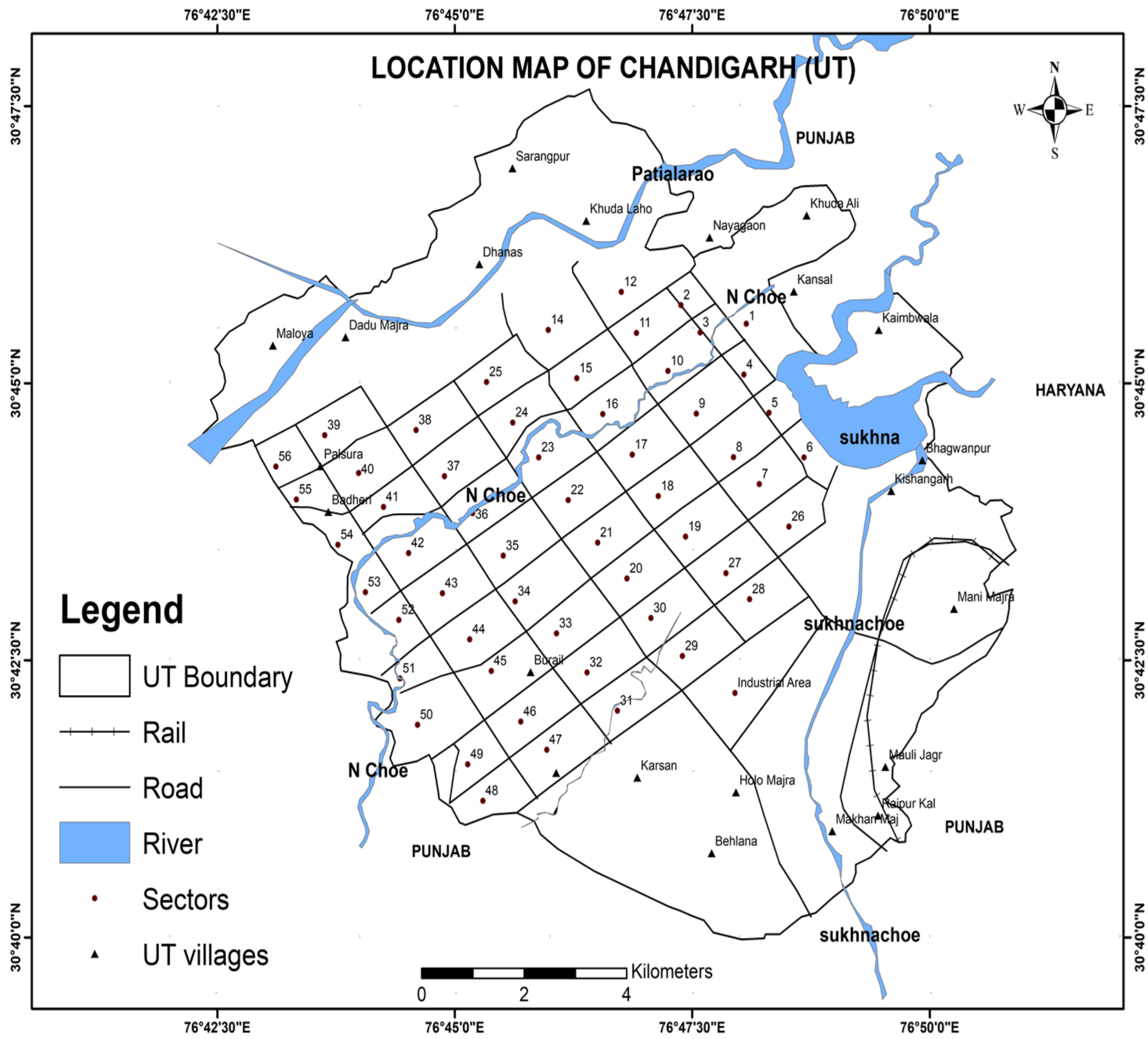
DYNAMIC GROUND WATER RESOURCES OF CHANDIGARH (UT) (AS ON 31st MARCH 2024)



CENTRAL GROUND WATER BOARD
NORTH WESTERN REGION, CHANDIGARH
AND
MUNICIPAL CORPORATION,
CHANDIGARH

MARCH, 2025

DYNAMIC GROUND WATER RESOURCES OF CHANDIGARH UT (AS ON 31st MARCH 2024)

Prepared by

CENTRAL GROUND WATER BOARD
NORTH WESTERN REGION
CHANDIGARH

AND

CHANDIGARH ADMINISTRATION &
MUNICIPAL CORPORATION, CHANDIGARH

MARCH, 2025

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क्षेत्रीय निदेशक (I/C)
जल शक्ति मंत्रालय
भारत सरकार

केन्द्रीय भूमि जल बोर्ड
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प्रस्तावना

केन्द्र शासित प्रदेश चंडीगढ़ के भूजल का सटीक आँकलन भारत सरकार की भूजल संसाधन आँकलन (GEC - 2015) संबन्धित दिशा निर्देशो के आधार पर 31 मार्च 2024 तक क्रियाशील संसाधनों का आँकलन किया गया। यह आँकलन केंद्रीय भूमिजल बोर्ड, उत्तरी पश्चिमी क्षेत्र, चंडीगढ़ एवं चंडीगढ़ प्रशासन एवं नगर निगम, चंडीगढ़ के अधिकारियों ने संयुक्त रुप से किया है। इस अध्ययन के लिये भारतीय प्रौद्योगिकी संस्थान, हैदराबाद द्वारा विकसित सॉफ्टवेयर (INGRES) का उपयोग किया गया है। सूचना प्रौद्योगिकी के उपयोग से यह अध्ययन कम समय में एवं सटीक रूप से पूर्ण हो पाया है। प्रस्तुत रिपोर्ट में पुनर्भरण माध्यम से भूजल की वार्षिक उपलब्धता, भूजल के मौजूदा दोहन एवं भविष्य में भूजल की शेष उपलब्धता का ब्लॉक स्तर पर किये गये विस्तृत आँकलन कर टेबल एवं ग्राफ के माध्यम से प्रस्तुत किया गया है। 2023-24 के अध्ययन में केंद्र शासित प्रदेश चंडीगढ़ को आधार बना कर आँकड़े प्रस्तुत किये गये है। इस अध्ययन से यह ज्ञान हुआ है कि केंद्र शासित प्रदेश चंडीगढ़ (एकमात्र ब्लॉक) ब्लॉक अर्ध विकट (Semi Critical) श्रेणी में है।

मैं श्री मनदीप सिंह बराड़, गृहसचिव, स्थानीय सरकार, चंडीगढ़ प्रशासन एवं अध्यक्ष आँकड़ा संशोधन समिति चंडीगढ़ यूटी (Committee for Estimation of Ground Water Resources Potential and Refinement of figures in UT of Chandigarh) के समय - समय पर दिये गये मार्गदर्शन एवं रिपोर्ट की स्वीकृति के लिये आभारी रहूँगा। मैं नगर निगम चंडीगढ़ से श्री एन. पी. शर्मा, मुख्य अभियंता एवं श्री हरजीत सिंह, अधीक्षण अभियंता, श्री परमिंदर पाल सिंघ अधिशाषी अभियंता एवं श्री संजीव चौहान उप-विभागीय अधिकारी के इस रिपोर्ट के संकलन में दिये गये सहयोग के लिए आभार प्रकट करता हूँ।

मैं केंद्रीय भूमिजल बोर्ड से श्री आदित्य शर्मा (वैज्ञानिक ख) द्वारा इस रिपोर्ट को तैयार करने के लिए दिए गये उनके महत्वपूर्ण योगदान के लिए उनका आभार प्रकट करता हूँ। मैं साथ ही श्री दिनेश तिवारी (वैज्ञानिक घ) जिनके पर्यवेक्षण में यह रिपोर्ट तैयार की गयी है, का भी आभार व्यक्त करता हूँ। मैं उन सभी अधिकारियो का भी आभार व्यक्त करता हूँ, जिन्होंने इस रिपोर्ट के संकलन में महत्वपूर्ण भूमिका निभाई है। मेरा विश्वास है कि यह रिपोर्ट योजनाकारों, प्रशासकों एवं जल व्यवस्थापन से जुड़े सभी विषयों के लिए महत्वपूर्ण रहेंगी।

विद्या नन्द

(विद्या नन्द)
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EXECUTIVE SUMMARY

Ground Water Resource Assessment is carried out at periodical intervals jointly by Municipal Corporation, Chandigarh UT and Central Ground Water Board under the guidance of the respective State Level Committee on Ground Water Assessment at State Levels and under the overall supervision of the Central Level Expert Group (CLEG). Such joint exercises have been taken up earlier in 1980, 1995, 2004, 2009, 2011, 2013, 2017, 2020, 2022, and 2023. From the year 2022, the exercise is being carried out annually. The assessment involves computation of dynamic ground water resources or Annual Extractable Ground Water Resource, Total Current Annual Ground Water Extraction (utilization) and the percentage of utilization with respect to annual extractable resources (stage of Ground Water Extraction). The assessment units (block) is categorized based on Stage of Ground Water Extraction, which are then validated with long-term water level trends.

Chandigarh is underlain by the Quaternary alluvial deposits and comprises layers of fine sand and clay. Coarser sediments occur along the Sukhna Choe and Patialiki Rao, whereas relatively finer sediments underlie the area between these two streams. Fair to good aquifer horizons occur in most part of Chandigarh comprising medium to coarse sand, to a depth of 180 m bgl below which they become finer. Ground water in the area occurs under confined as well as semi-confined conditions. In Manimajra, ground water occurs under unconfined conditions down to about 80 m. In other areas, the semi-confined conditions prevail below 20 to 30 m. The depth of the shallow aquifer system is less than 30 m bgl, whereas the depth of the deeper aquifer system ranges from 40 to 450 m bgl of explored depth. Ground water is found to be fresh and suitable for drinking as well as irrigation purposes. UT of Chandigarh has very small area of 114 sq. km and whole UT has been taken as an assessment unit.

Total Annual Ground Water Recharge has been assessed as 0.06 bcm and Annual Extractable Ground Water Resources as 0.05 bcm. The UT of Chandigarh has been categorized as ‘Safe’ with Total Extraction of 0.03 bcm and stage of ground water extraction at 66.13 %. Out of 114 sq. km recharge worthy area of the UT, 100 % of the area is under ‘Safe’. The entire 49.62 mcm annual extractable ground water resources of the UT, is under ‘Safe’ categories of assessment units. In comparison to 2023 assessment, Total annual recharge has increased marginally from 0.054 bcm to 0.055 bcm owing to increased rainfall recharge. The current ground water extraction has marginally decreased from 0.036 bcm to 0.032 bcm.

CHAPTER-1: INTRODUCTION

1.1 Introduction

Chandigarh known, as "THE CITY BEAUTIFUL" is a Union Territory (U.T.) located at the foothills of the Siwaliks about 250 km north of Delhi. The city also has the distinction of being the joint capital of Punjab and Haryana states even though it does not form part of any of the two States. It lies between north latitudes 30°40' and 30°46' and east longitudes 76°42' and 76°51' and falls in Survey of India toposheet no. 53B/13 & 53B/14. Punjab state borders the UT in the south and southwestern sides and Haryana state on eastern side. UT of Chandigarh has an area of 114 sq. km, out of which 36 sq.km. is rural and remaining 78 Sq.km, is urban. The city is divided into 55 dwelling sectors. As per census 2011, total population of the city was 10,55,450 persons having a population density of 9258 persons/sq.km. Due to high urbanization, almost 79% of the total area is not available for cultivation. Main crops grown during Kharif are rice, maize and, potato while during Rabi season wheat, gram and oil seeds are grown.

There are 248 nos. of deep tube wells in the city for drinking & domestic use and total domestic draft is 2513.54 ham /year and 23 nos. of tube wells for commercial use / industrial use are permitted to withdraw ground water 217.66 ham/year and 30 nos. of tube wells are used for irrigation use and total draft of these wells are 550.50 ham/year.

There are no large natural surface water bodies in Chandigarh though small ponds do exist in the rural areas. The Sukhna Choe has been dammed in northeast side of the city, which has given rise to an artificial lake covering an area of about 1.99 sq. km. The lake, known as Sukhna, has a water holding capacity of 5 million cubic meters (MCM). UT of Chandigarh falls in the Ghaggar Basin. There are two major streams, Sukhna Choe and Patiali ki Rao that originate from Siwalik Hills ranges and forms the natural drainage of the city. The Sukhna Choe flows north to south, drains the eastern part and joins the Ghaggar River. The other important stream is Patiala-ki Rao, which flows northeast to southwest and drains the northern parts of the city. Both these streams are ephemeral in nature and carry high flows during monsoon. The N-Choe flows through the leisure valley and drains major parts of the city. It flows from northeast to southwest direction and traverses north central part of the city. Another Choe, Choi Nala originates from Sector-31 and drains southernmost part of the city.

1.2 Background for Re-Estimating the Ground Water Resources of the Union Territory

The first attempt to estimate the ground water resources of the country was made in the year 1979. A committee known as Ground Water Over-exploitation committee was constituted by Agriculture Refinance and Development Corporation (ARDC) of Govt. of India. Based on the methodology and norms recommended by the above Committee, the ground water resources were assessed. Subsequently, the necessity was felt to refine the methodologies and the "Ground water Estimation Committee (GEC)" headed by the Chairman, CGWB came into existence. Based on the detailed surveys and studies by the various offices and projects of CGWB, the Committee recommended the revised methodology in 1984 (GEC-84) for estimation of ground water resources. Again in 1997, the Ground Water Estimation Committee reviewed the previous studies and work done in various states and suggested a modified methodology (GEC-97) for computation of ground water resources. Accordingly, the Dynamic Study of Ground Water Estimation in the Chandigarh UT has been carried out on the basis of GEC-97 Methodology.

In 2010, Ministry of Water Resources constituted a Central Level Expert Group (CLEG) for over all supervision of the reassessment of ground water resources in the entire country. The group finalized its report and the draft report was circulated to all the members of the Committee for their views. During the fourth meeting of the committee, held on 03-12-2015, the draft report of "Ground Water Resource Estimation Committee - 2015 (GEC 2015) was discussed in detail. The views expressed by the members for revised methodology were considered and necessary modifications were made and report of the Committee was finalized. As decided in the meeting held on 09.02.2016 at New Delhi on Revision of Ground water estimation Methodology-97, a workshop on "Ground Water Resource Estimation Methodology - 2015" was held on 24th January 2017 at CWPRS, Khadakwasla, Pune involving stakeholders and experts. The major changes proposed in the workshop were (i) to change the criteria for categorization of assessment units and (ii) to remove the potentiality tag.

The Ministry of Water Resources also requested all the State/UT Governments to constitute State Level Committees for overall supervision of assessment of ground water resources at the state level. As per guidelines of Central Ground Water Board, Chandigarh UT Government, vide Endst. No. 16501-FII(9)-2020/12910 dated 01/11/2020**,** has notified a committee namely: "**State Level Evaluation Committee**" for estimation annual replenishable ground water resources in accordance with the Ground Water Resources Estimate Methodology.

1.3 Constitution of State-Level Committee for Ground Water Resources Estimation

In an attempt to re-assess the ground water resources of Chandigarh UT based on GEC-2015 methodology, Chandigarh UT administration has constituted a state level committee with the following members.

1.	The Secretary, Local Govt., Chandigarh Administration	**Chairperson**
2.	The Chief Conservator of Forest, U.T, Chandigarh	**Member**
3.	The Commissioner, U.T, Chandigarh	**Member**
4.	The Deputy Commissioner, U.T Chandigarh	**Member**
5.	The Chief Engineer, M.C Chandigarh	**Member**
6.	The Chief Engineer, U.T Chandigarh	**Member**
7.	The Director Industries, U.T, Chandigarh	**Member**
8.	The General Manager, National Bank for Agriculture and Rural Development (NABARD), Sec 34, Chandigarh	**Member**
9.	The Director, India Meteorological Department, Chandigarh	**Member**
10	The Superintending Engineer, UT, Chandigarh	**Member**
11	The Superintending Engineer, MC, Chandigarh	**Member**
12	The Regional Director, Central Ground Water Board (CGWB), sec 27, Chandigarh	**Member Secretary**

CHAPTER-2 HYDROGEOLOGICAL CONDITIONS OF THE UNION TERRITORY CHANDIGARH

2.1 Hydrogeology

The Union Territory of Chandigarh is occupied by semi consolidated formations of upper Siwalik system of middle Miocene age that are exposed in north eastern fringe whereas the rest of the Territory is occupied by Indo Gangetic plain comprising alluvium of Pleistocene age. The piedmont deposits at the foot of Siwalik Hills comprise cobble, pebble and boulder, associated with sand, silt and clay. The piedmont deposits are followed by alluvial plain comprised of clay, silt and sand.

The formations have been deposited by the drainage system originating in the Siwaliks. Coarser sediments occur along the Sukhna Choe and Patiali ki Rao whereas relatively finer sediments, thus restricting the aquifer disposition laterally, underlie the area between these two streams. The typical Kandi formations comprising boulders-gravel- coarse sand are not prevalent in the area since the source formations are fine grained.

Four physiographic units are encountered in Chandigarh; **The Siwalik range** trending NW-SE forms the northeastern boundary of Chandigarh and is exposed in a small patch on the northeastern side. Southwestern slopes of the foothills are covered with loose talus material deposited by hill torrents forming alluvial fans. These alluvial fans coalesce to form piedmont **Kandi** formation running parallel to the hill ranges. The piedmont deposits comprise of cobble, pebble and boulder, associated with sand, silt and clay. The Kandi formations merge into **Sirowal** formations in south and southwest. The Sirowal merges with the main **Alluvial plain** towards south and southwest. The alluvial deposits belong to Quaternary age and comprise layers of fine sand and clay. Coarser sediments occur along the Sukhna Choe and Patiali ki Rao whereas relatively finer sediments, thus restricting the aquifer disposition laterally, underlie the area between these two streams. The typical Kandi formations comprising boulders-gravel- coarse sand are not prevalent in the area since the source formations are fine grained. Water table elevation study reveals that the flow of ground water is from north to southwest and southern directions. Water table elevation difference between northern and southwestern parts is 20 m and lies between 330 m amsl and 310 m amsl. Due to this hydraulic difference the ground water moves from north to southwestern direction. In western area ground water flow is towards Patiala-ki- Rao and it flows parallel to Sukhna Choe. The ground water flow from extreme north to southwestern part suggests that ground water recharge takes place from recharge area running parallel to Siwaliks.

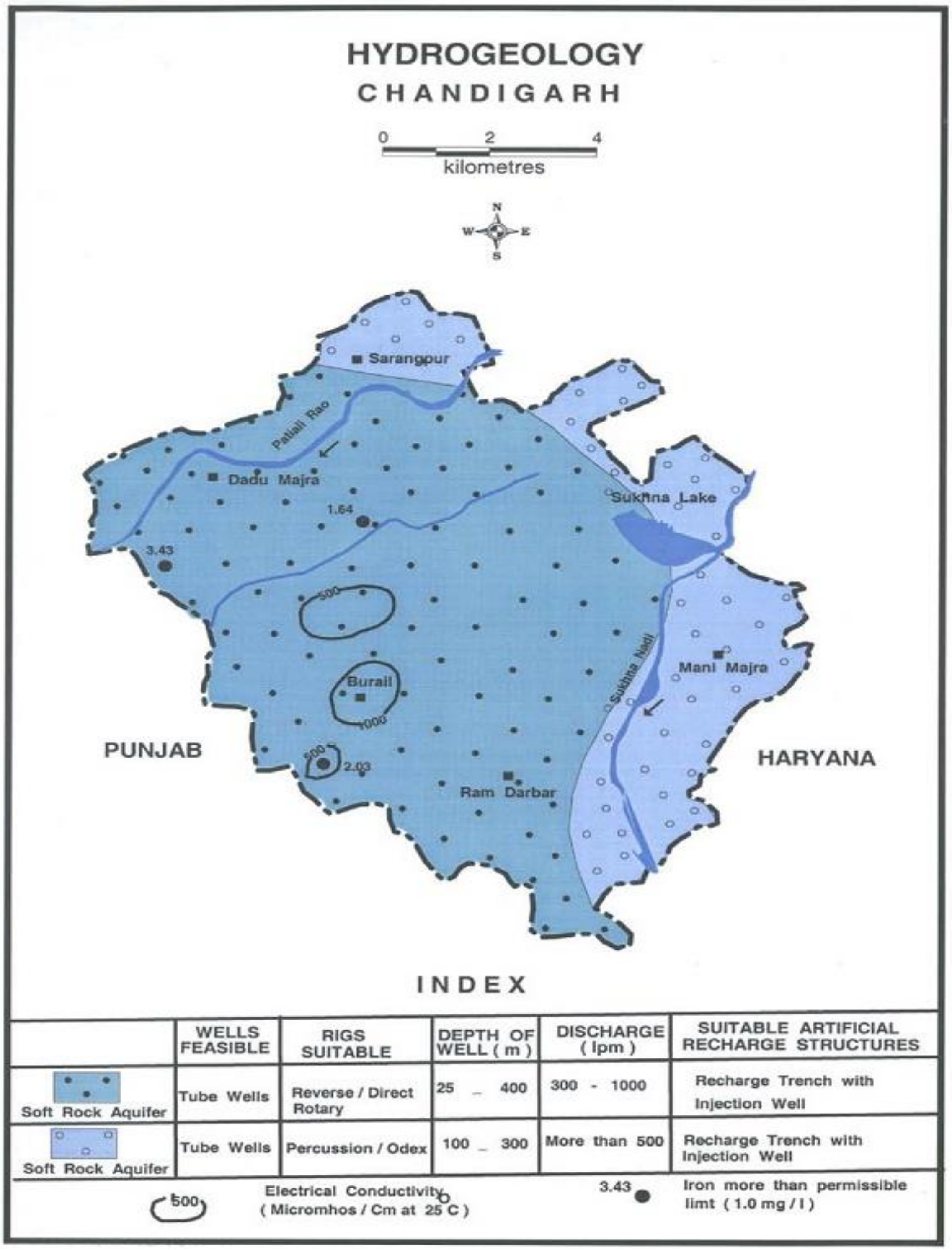


Figure 1: Hydrogeology Map of Chandigarh UT

Ground water in the area occurs under water table, confined as well as semi- confined conditions. The pumping test data of the aquifers tested in the city clearly indicates that good confined aquifers occur around sector 10,33, 38 and 47 while leaky are encountered around sector 28. One interesting feature is that the aquifers in the southern parts of the city are restricted in aerial extent due to lithological boundaries as deciphered from pumping test data. Ground water occurs under unconfined conditions down to about 80 m in Manimajra area. In other areas the semi-confined conditions prevail up to 20-30 m below land surface. Barring Manimajra area ground water below 2030 m exist under confined conditions.

The depth of the shallow aquifer system is less than 30m below ground level whereas the depth of the deeper aquifer system ranges from 40 to 450 mbgl of explored depth while in Manimajra area confined aquifers occur below 90 m. During the exploratory drilling operations in the city in the year 1972-74 only deep (100-300 m) exploratory wells were constructed and aquifer performance tests were conducted. The transmissivity values for the deeper aquifer system ranged between 74 m2/day at sector 10 to 590 m2/day at sector 28. The storativity values ranged between 1.5x10-4 to 7.5x10-4 indicating confined nature of aquifer systems. A number of aquifer performance tests were also conducted on the existing shallow tubewells and only the recovery data was used to assess the aquifer parameters. The transmissivity values of shallow aquifers up to 100 m depth range obtained during these tests ranged between 70 and 466 m2/day.

2.2 Hydrometeorology

Chandigarh (UT) has a humid subtropical climate characterized by a seasonal rhythm: very hot summers, mild winters, unreliable rainfall and great variation in temperature. The city also receives occasional winter rains from the western disturbance originating over the Mediterranean Sea. The western disturbances usually bring rain predominantly from mid-December to till end of April which can be heavier sometimes with strong winds and hails if the weather turns colder (during March–April months) which usually proves disastrous to the crops. Cold winds usually tend to come from the north near Shimla, and from the State of Jammu and Kashmir, both of which receive their share of snowfall during winter time. Most of the year, the climate of Chandigarh (UT) is of a pronounced continental character, very hot in summer and markedly cold in winter. In between are the pleasant months of spring. There is extremely hot in summer at around 45 °C and mild in winter. The hottest months are May and June and the coldest are December and January. Normal minimum temperature ranges from 3°C to 9°C. Temperature dips to freezing point during the month of December/January. The air over the entire UT is dry during the greater part of the year. Humidity is high in the monsoon months. April and May are the driest months with relative humidity of about 30% in the morning and less than 20% in the afternoons. Winds are generally light during the post monsoon and winter months. They strengthen during the summer and monsoon months. Except during the monsoon months, winds are predominantly from a westerly or north-westerly direction and tend to be more northerly in the afternoon. Easterly and south-easterly winds are more common in the monsoon months.

2.2.1 Rainfall

There are two seasons of rainfall in the UT. The south-west monsoon season, the principal source of ground water sets in last week of June and withdraws towards end of September and contributes about 80% of annual average rainfall. Another period of rainfall is winter rain from December to March is about 20% of total rainfall which is mostly absorbed into the soil. More than 50% of the annual rainfall received in the four rainy months for June to September, only there by leading to large variations on temporal scale. Rainfall is highly variable in time and space.

The Normal Rainfall for Chandigarh (UT) 1078 mm, but it has great spatial variations. The Actual annual rainfall since 2012 to 2023, of Chandigarh (UT) analyzed and compared to the normal rainfall, then it is observed that rainfall pattern is showing decline trend and continuously deficient rainfall 2012 (-7%), 2013 (-5%), 2014 (-24%), 2015 (-24%), 2016 (-47%), 2017 (-20%), 2018 (+1%), 2019 (-13%), 2020 (-20%), 2021 (-24%), 2022 (+12%) & 2023 (+45%) observed in Chandigarh UT.

ITEM	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Normal Rainfall (mm)	1078	1078	1078	1078	1078	1078	1078	1078	1078	1078	1078	1078
Actual Rainfall (mm)	1004	1026	819	824	575	858	1086	940	867	819	1210	1563.2
% Departure From Normal	-7	-5	-24	-24	-47	-20	+1	-13	-20	-24	+12	+45

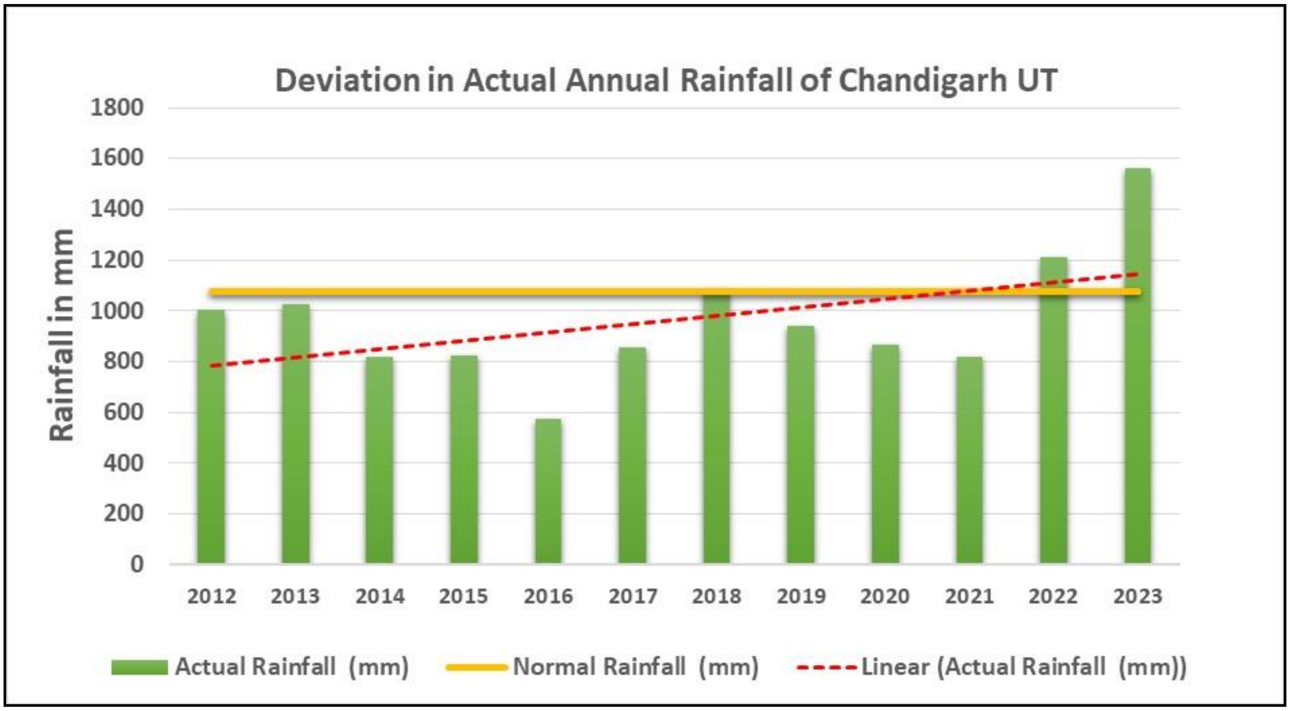


Figure 2: Deviation in Actual Annual Rainfall of Chandigarh UT

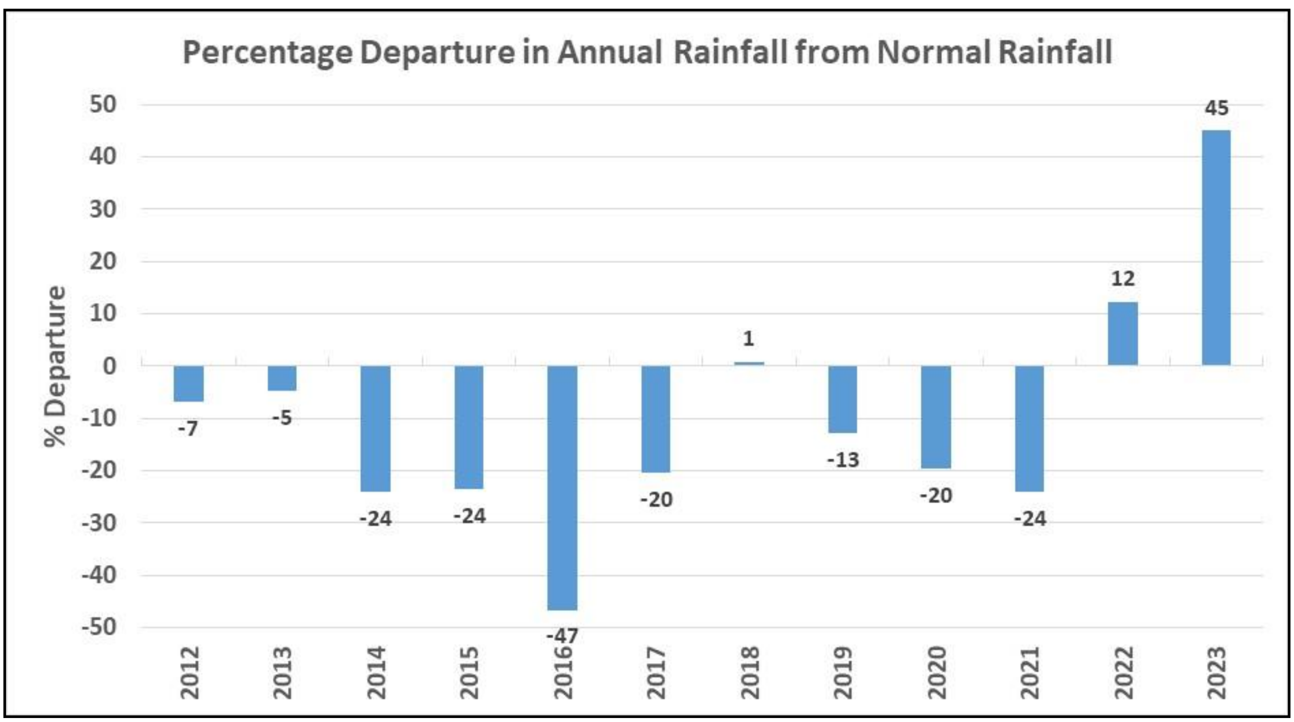


Figure 3: Percentage Departure in Annual Rainfall from Normal Rainfall of Chandigarh UT

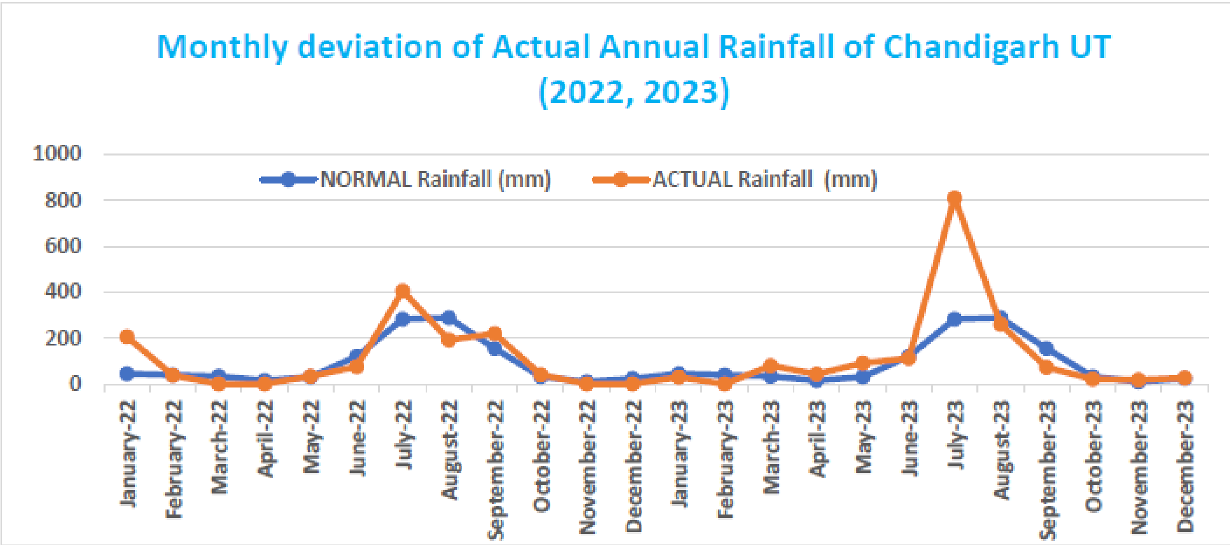


Figure 4: Monthly Deviation of Actual Annual Rainfall of Chandigarh UT

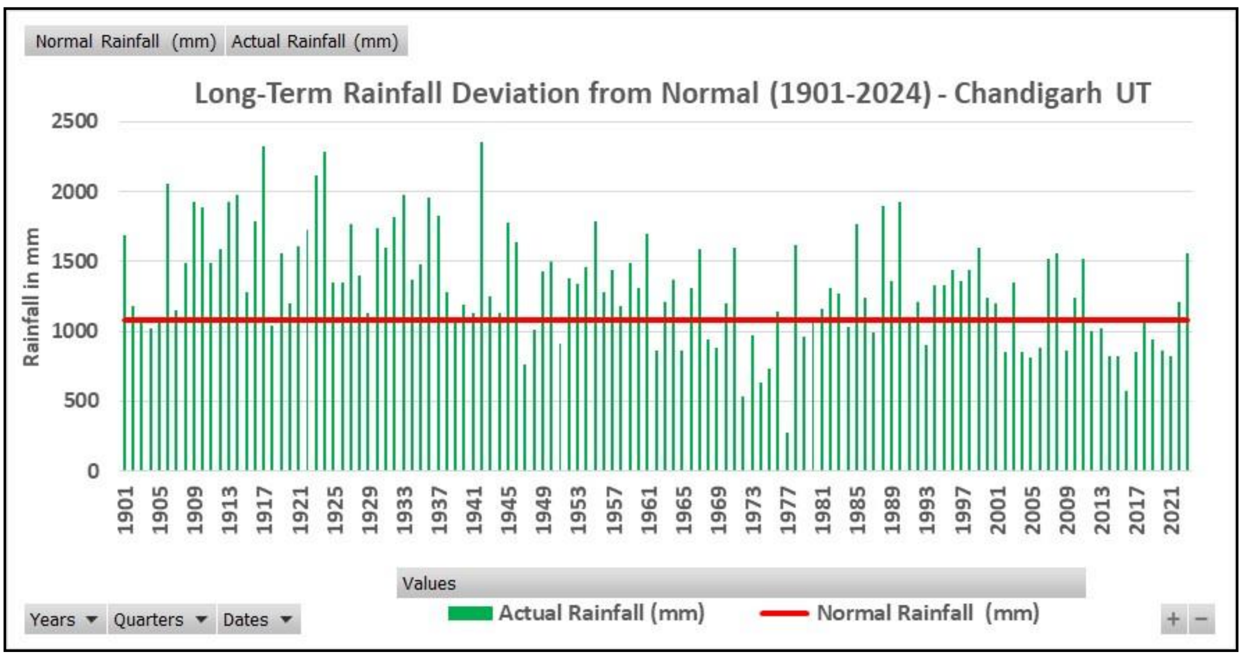
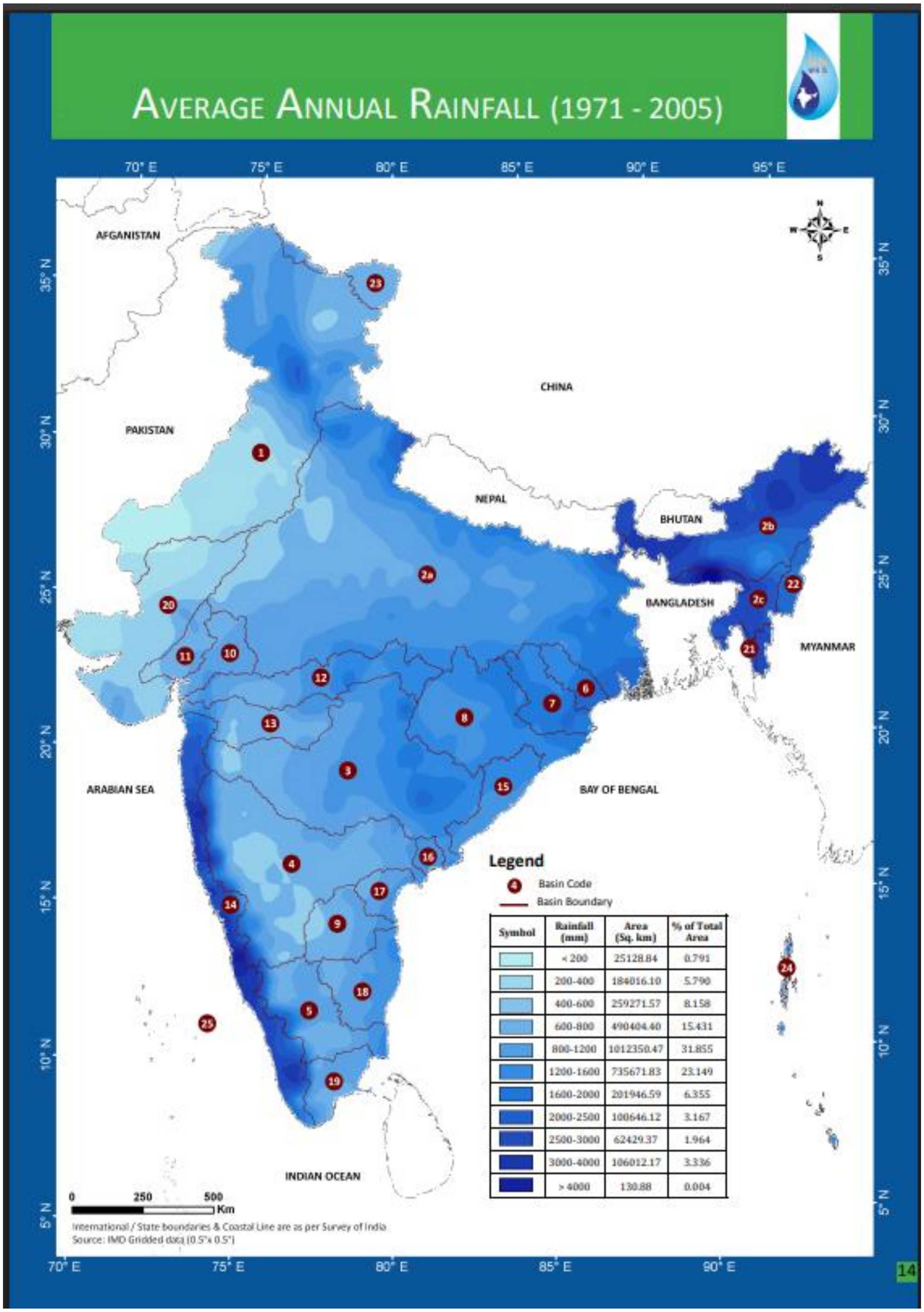


Figure 5: Long Term Rainfall Deviation from Normal (1901-1924) - Chandigarh UT



Symbol	Rainfall (mm)	Area (Sq. km)	% of Total Area
	< 200	25128.84	0.791
	200-400	184016.10	5.790
	400-600	259271.57	8.158
	600-800	490404.40	15.431
	800-1200	1012350.47	31.855
	1200-1600	735671.83	23.149
	1600-2000	201946.59	6.355
	2000-2500	100646.12	3.167
	2500-3000	62429.37	1.964
	3000-4000	106012.17	3.336
	> 4000	130.88	0.004

Figure 6: Average Annual Rainfall of India (1971-2005)

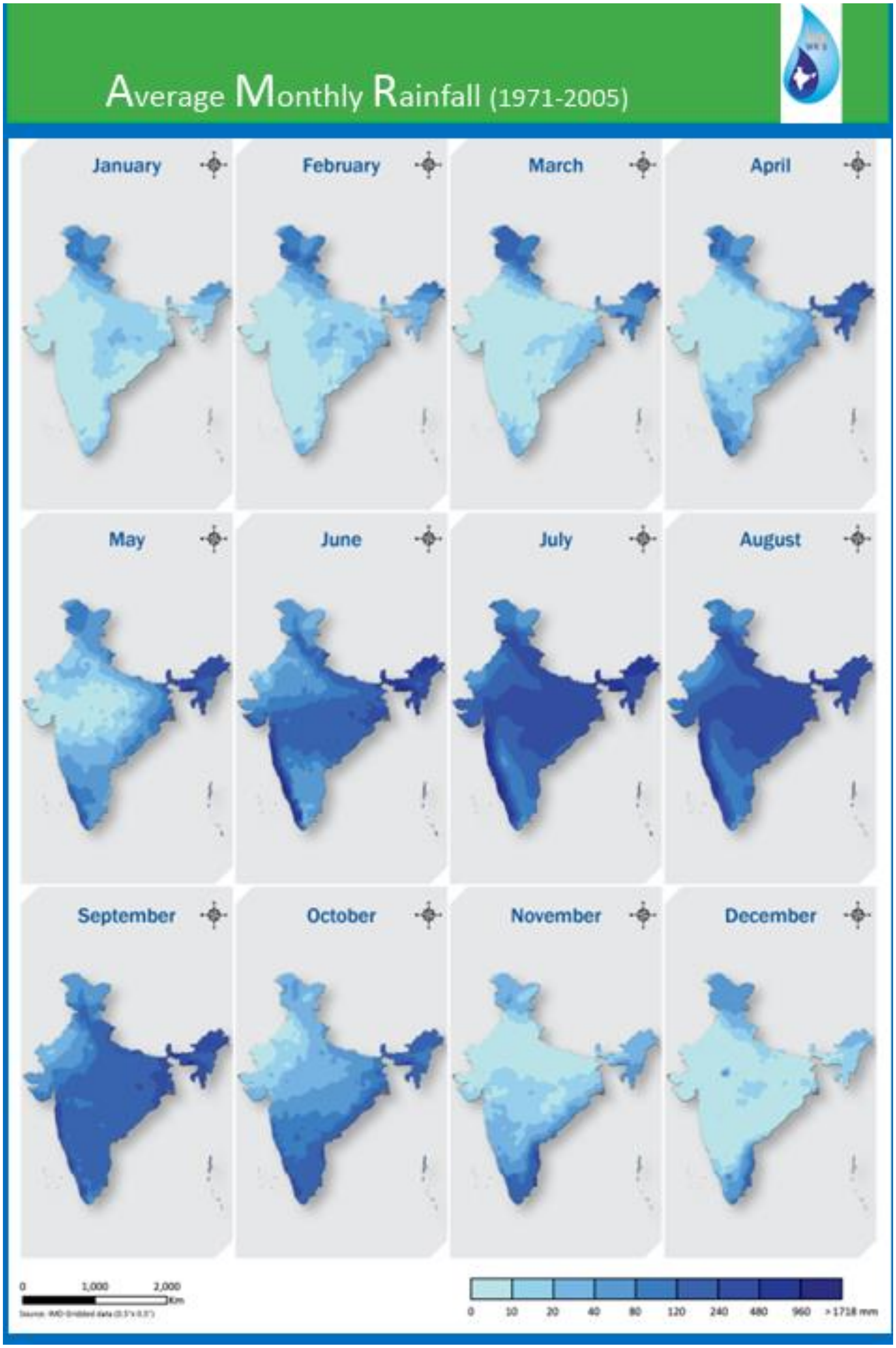


Figure 7: Average Monthly Rainfall of India (1971-2005)

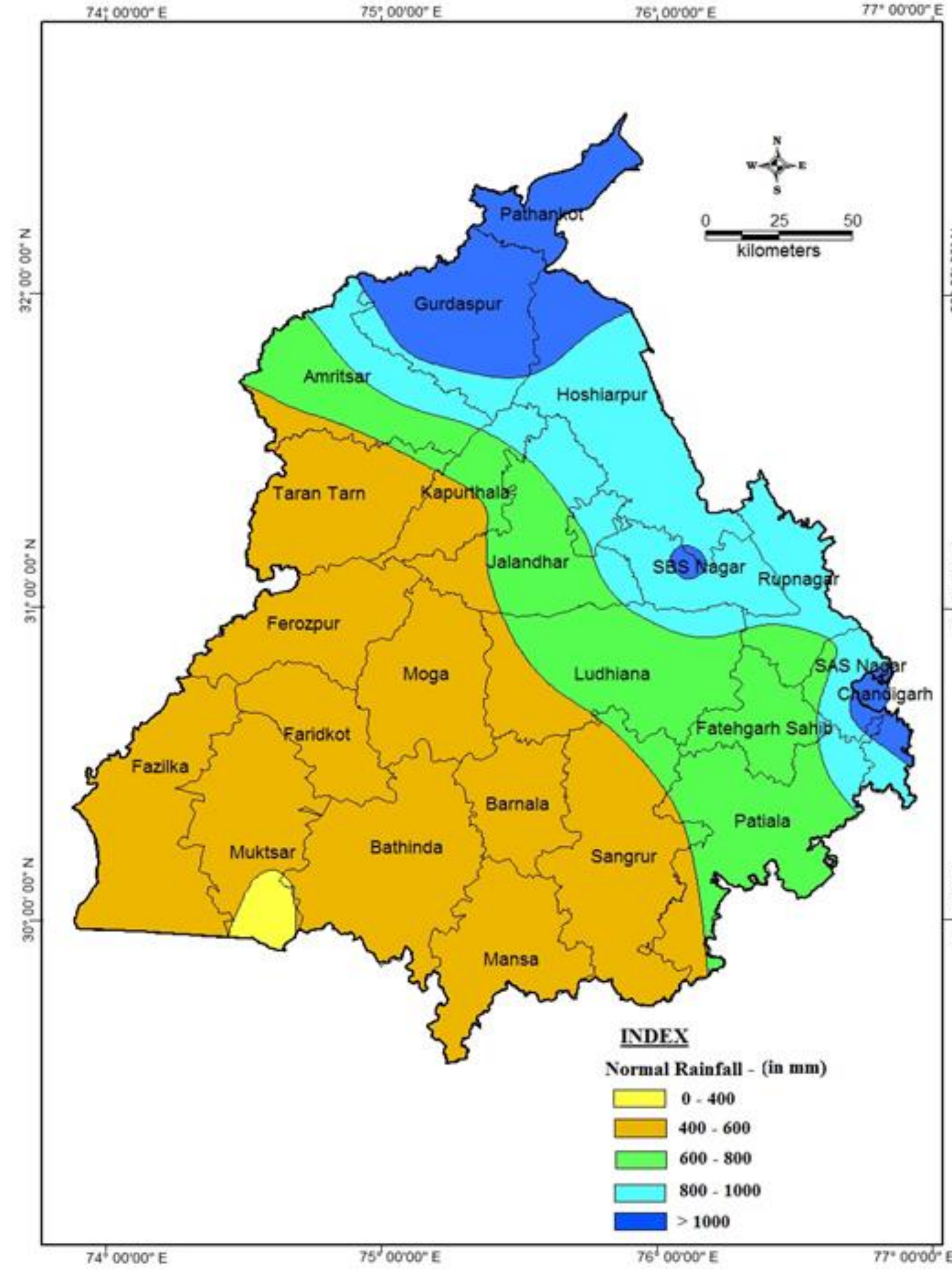


Figure 8: Isohyet Rainfall Map of Punjab & Chandigarh

2.3 Aquifer Disposition and Characteristics

Based on the exploratory drilling carried out by Central Ground Water Board down to a depth of 450 mbgl, it can be concluded that fair to good aquifer horizons occur in most part of Chandigarh except in south-western parts near sectors 37, 38, 39, 40 and 41. A 20 meter thick aquifer at a depth of 160 mbgl, occurs in almost all of Chandigarh except around sector 38 which comprises of medium to coarse sand. It has also been inferred that the sediments are relatively coarse-grained down to a depth of 180 mbgl below which they become finer. The yield of the deeper aquifers is also lesser as compared to the shallower ones.

The formations encountered in a borehole drilled down to 465 mbgl in sector 28 close to Sukhna Choe, are well-defined coarse sediments up to 240 mbgl. Below this depth the formations are finer grained. Whereas the shallow formations comprise coarse sand to gravel and pebbles intercalated with clays, the deeper ones are fine sands and silts. In sector 47, the aquifer material is coarse down to a depth of 174 mbgl below which it becomes finer. The aquifer material encountered at sector 33 is coarse down to 180 mbgl. This indicates that the thickness of coarser sediments is greater in northern parts of the city as compared to the southern parts. Along Sukhna Choe, three prominent sand beds occur (inter-bedded with clay beds) within a depth of about 100 m. The upper sand beds are about 15 m thick and occur 8 m below land surface. Middle sand bed is about 18 m thick and occurs at depths varying from 21 to 38 mbgl. The deeper sand bed occurs at depth varying from 39 to 76 mbgl and is about 27 m thick. These beds are more persistent in the downstream direction of Sukhna Choe.

Ground water in the area occurs under water table, confined as well as semi-confined conditions. The pumping test data of the aquifers tested in the city clearly indicates that good confined aquifers occur around sector 10, 33, 38 and 47 while leaky are encountered around sector 28. One interesting feature is that the aquifers in the southern parts of the city are restricted in aerial extent due to lithological boundaries as deciphered from pumping test data. Ground water occurs under unconfined conditions down to about 80 m in Manimajra area. In other areas the semi-confined conditions prevail up to 20-30 m below land surface. Barring Manimajra area ground water below 20-30 m exist under confined conditions. The depth of the shallow aquifer system is less than 30 m below ground level whereas the depth of the deeper aquifer system ranges from 40 to 450 mbgl of explored depth while in Manimajra area, confined aquifers occur below 90 m. The transmissivity values for the deeper aquifer system ranged between 74 m^2/day at Sector 10 to 590 m^2/day at Sector 28. The storativity values ranged between 1.5×10^{-4} to 7.5×10^{-4} indicating confined nature of aquifer systems. A number of aquifer performance tests were also conducted on the existing shallow tubewells and only the recovery data was used to assess the aquifer parameters. The transmissivity values of shallow aquifers up to 100 m depth range obtained during these tests ranged between 70 and 466 m^2/day.

2.4 Groundwater level conditions

The depth to water level in the shallow aquifer system in pre-monsoon season varies from 3.62 m bgl (Sector 44) in the southern sectors to 34.25 m bgl (Sector 10) in the northern sectors. In the western and southwestern part of the city covering sectors 37 to 46 the water level is shallow i.e. less than five meters. This is due to fine nature of sediments and lithlogical boundaries. In the northern sectors, the water levels are more than 7.0 m bgl. During the post monsoon, the water level varies from 3.49 (Sector 44) in the southern part to 34.45 m bgl (Sector 10) in the northern part of the city. The water level in the deeper aquifer system ranges between 20.17 (Sector 39) to 65.02 (Sector 46) m bgl during pre-monsoon and 15.65 (Sector 39) to 62.66 (Sector 46) m bgl in post monsoon. The long-term water level fluctuation (decadal) of the deep aquifer system shows that in all part of city, there is significant decline trend in the range between 0.32 to 1.55 m/year. This fall in water level is attributed to heavy pumping from the deeper aquifer for domestic and agricultural purposes.

Depth to Water Level Map in Shallow aquifers (Pre-& Post monsoon, 2023)

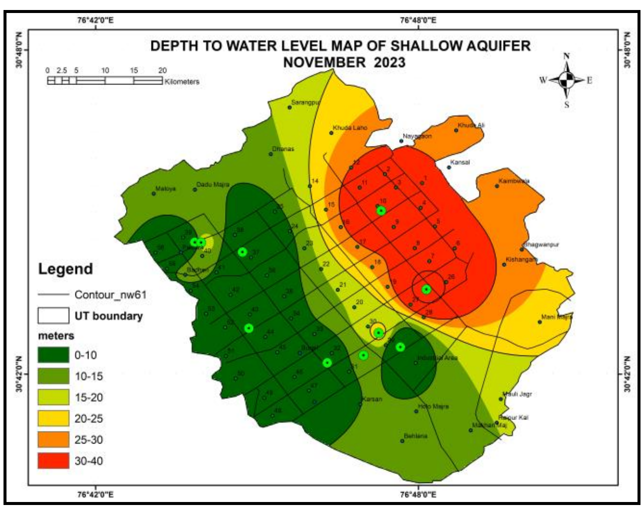


Figure 9: Pre-Monsoon 2023 ***in Shallow aquifers***

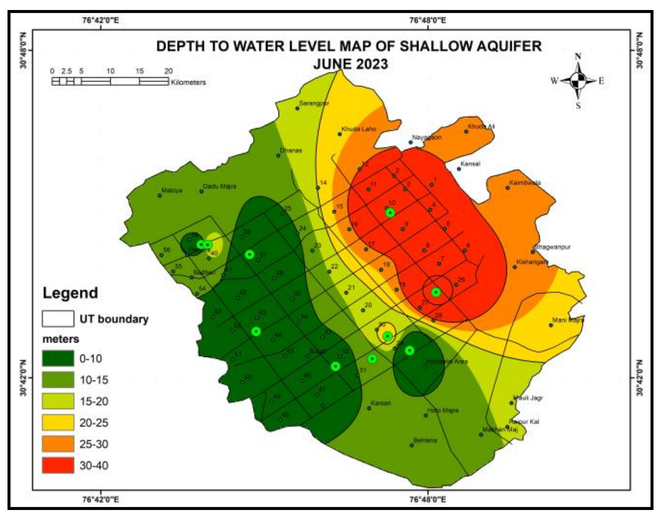


Figure 10: Post Monsoon 2023 ***in Shallow aquifers***

Depth to Water Level Map in deeper aquifers (Pre-& Post monsoon, 2023)

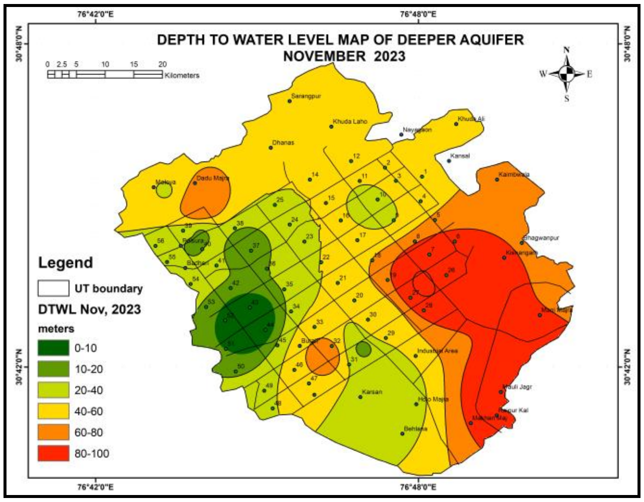


Figure 11: Pre-Monsoon 2023 ***in Deep aquifers***

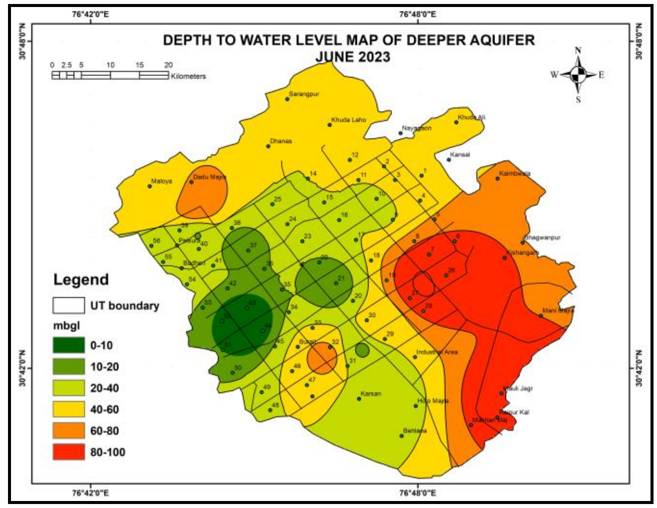


Figure 12: Post Monsoon 2023 ***in Deep aquifers***

2.5 Ground Water Quality

Based on the data generated from the analysis of ground water samples drawn from hand pump and tube wells, it is found that the ground water is fresh and suitable for drinking as well as irrigation purposes. Normally, the ground water drawn from the deeper aquifers is less mineralized as compared to water drawn from shallow aquifers. Geochemical facies evaluation of ground water indicates that most of the waters, both from shallow and deeper aquifer, are of Ca-HCO_3 type. Concentration of some of the vital quality indicators such as F, NO_3, salinity, and hardness is within permissible limits of drinking water standards (BIS -2012). Analysis of trace elements in ground water indicated that concentration of copper, iron and manganese in some of the shallow hand pump waters is above maximum permissible limit for drinking waters. As far as deeper tube well waters are concerned, none of the water sample registered higher concentration of any of the metal analyzed.

2.6 COMPOSITION OF GROUND WATER

Ground Quality of shallow ground water of Chandigarh is evaluated through 8 samples collected during June-2023. The water samples were analyzed for major cations (Ca, Mg, Na, K) and anions (CO3, HCO3, Cl, NO3, SO4F, PO4) in addition to pH, EC, SiO2 and TH as CaCO3 in the Regional Chemical Laboratory by following 'Standard analytical procedures' as given in APHA 2017.

The results of chemical analysis of ground water sample (Appendix-VIII) reveals that it is alkaline in nature with pH from 7.57 to8.25 and moderately mineralized with EC ranging from 229 to 870 µS/cm. at 250C. Among anions, carbonate ion is found to vary between nil whereas bicarbonate concentration ranges from 61 to 439 mg/l. The chloride values range from 14 to 57 mg/l, while the Sulphate values vary from 5 to 24 mg/l. Nitrate concentrations are found to range between 1.4 to be 18 mg/l. The Fluoride content is 0.45 mg/l and maximum concentration is 1.27 mg/l which is above the desirable limit of 1.0 mg/l.

The cations such as calcium and magnesium are present in low concentration and their highest values are 56 mg/l and 51 mg/l, respectively. The sodium concentration varies between 5.8 to 106 mg/l. The maximum potassium concentration reported is 8.7 mg/l. Total hardness of water sample expressed as CaCO3 is found to range between 110 and 270 mg/l. The perusal of Trilinear Plot of percentages of major ions represented on Piper Diagram (Plate 3), indicates that different types of water is found in the area, varying from Ca-MgHCO3.

The ground water is suitable for domestic use as all parameters are within the permissible limits of drinking water quality standards prescribed by BIS-2012. The suitability of groundwater for irrigational uses is determined by considering the values of salinity (EC), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC). Based on highest reported values for EC (582 µS/cm.), SAR (2.91) and RSC (2.20), it can be concluded that groundwater of Chandigarh is suitable for irrigation. The USSL classification of irrigation waters (Plate 4) indicates that it falls in C2S1 class and can be used for customary irrigation.

Temporal Variation On comparison with chemical data of GWMS 2020, there is improvement in water quality in term of Salinity (with respect to EC), Nitrate and Fluoride during this period. Conclusion & Recommendation Conclusion drawn for quality evaluations of ground water and its suitability for various uses is based on macro level studies through monitoring stations sampled during 2023. It can be concluded that in Chandigarh ground water is generally suitable for drinking and groundwater is suitable for irrigation purposes.

2.6.1 Conclusion & Recommendation

Conclusion drawn for quality evaluations of ground water and its suitability for various uses is based on macro level studies through monitoring stations sampled during 2023. It can be concluded that in Chandigarh ground water is generally suitable for drinking and groundwater is suitable for irrigation purposes.

Drinking Water Characteristics (IS 10500: 2012)

S.No.	Parameters	Desirable Limits(mg/L)	Permissible Limits(mg/L)
EssentialCharacteristics			
1	Colour Hazen Unit	5	15
2	Odour	Unobjectionable	-
3	Taste	Agreeable	-
4	Turbidity(NTU)	1	5
5	pH	6.5-8.5	No relaxation
6	Total Hardness,$CaCO_3$	200	600
7	Iron(Fe)	1.0	No relaxation
8	Chloride(Cl)	250	1000
9	Residual Free Chlorine	0.2	1
10	Fluoride(F)	1.0	1.5
DesirableCharacteristics			
11	Dissolved Solids	500	2000
12	Calcium(Ca)	75	200
13	Magnesium(Mg)	30	100
14	Copper(Cu)	0.05	1.5
15	Manganese(Mn)	0.1	0.3
16	Sulphate(SO_4)	200	400
17	Nitrate(NO_3)	45	Norelaxation
18	Phenolic Compounds	0.001	0.002
19	Mercury(Hg)	0.001	Norelaxation
20	Cadmium(Cd)	0.003	Norelaxation
21	Selenium(Se)	0.01	Norelaxation
22	Arsenic(As)	0.01	Norelaxation
23	Cyanide(CN)	0.05	Norelaxation
24	Lead(Pb)	0.01	Norelaxation
25	Zinc(Zn)	5.0	15
26	Hexavalent Chromium	0.05	Norelaxation
27	Alkalinity	200	600
28	Aluminum(Al)	0.03	0.2
29	Boron(B)	0.5	2.4
30	Pesticides	Absent	0.001
31	Uranium	0.03	Norelaxation

NTU-Nephelometric TurbidityUnit

Ground Water Quality Parameters in Ground water Samples ofUT, Chandigarh

Sl. No.	State	District	Location	Latitude	Longitude	ECµS/cm	Cl in mg/L	F in mg/L	NO3in mg/L	Fe in mg/L	As (ppb)	U (ppb)
1	Chandigarh UT	Chandigarh	Burail	30.7101	76.7592	870	57	1.27	1.4	0.021	2.127	1.929
2	Chandigarh UT	Chandigarh	IMD Sector 39	30.7400	76.7310	229	36	0.45	2.3	0.014	1.896	2.079
3	Chandigarh UT	Chandigarh	Maloya	30.7519	76.7182	679	57	0.96	6.1	0.313	0.279	0.763
4	Chandigarh UT	Chandigarh	New Karsan Colony	30.6928	76.7929	520	14	0.97	2.7	0.017	0.226	3.450
5	Chandigarh UT	Chandigarh	Sector 10C	30.7550	76.7940	285	36	0.56	1.6	0.017	0.511	1.774
6	Chandigarh UT	Chandigarh	Sector 31	30.7036	76.7759	700	43	0.93	9.0	0.031	0.203	6.267
7	Chandigarh UT	Chandigarh	Sector 39-D	30.7430	76.7280	621	43	0.92	18	0.304	0.136	8.413
8	Chandigarh UT	Chandigarh	Sector-46	30.7030	76.7690	270	21	0.50	2.5	0.008	1.759	2.298

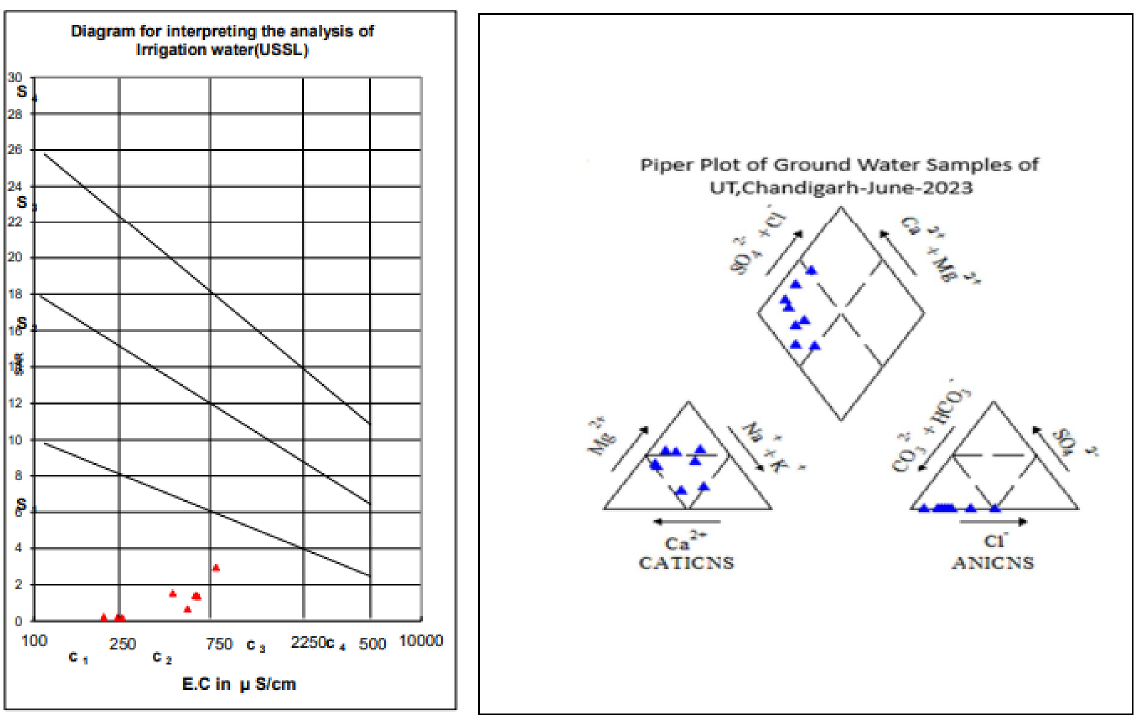


Figure 13: Piper Diagram & USSL Diagram of Ground Water Quality

CHAPTER-3 GROUND WATER RESOURCES ESTIMATION METHODOLOGY

The revised methodology GEC 2015 recommends aquifer wise ground water resource assessment. Ground water resources have two components – Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources. GEC 2015 recommends estimation of Replenishable and in-storage ground water resources for both unconfined and confined aquifer. Wherever the aquifer geometry has not been firmly established for the unconfined aquifer, the in-storage ground water resources have to be assessed in the alluvial areas up to the depth of bed rock or 300 m whichever is less. In case of hard rock aquifers, the depth of assessment would be limited to 100 m. In case of confined aquifers, if it is known that ground water extraction is being taken place from this aquifer, the dynamic as well as in-storage resources are to be estimated. If it is firmly established that there is no ground water extraction from this confined aquifer, then only in-storage resources of that aquifer have to be estimated.

3.1 Periodicity of Assessment

Keeping in view of the rapid change in Ground Water Extraction, the committee recommends more frequent estimation of Ground Water Resources. As per recommendation of Committee, the resources are to be assessed every year from 2022 onwards. As per the present practice, there was a considerable time lag between assessment and publication of the results; however, the introduction of INGRES has made it possible to reduce the time lag and the results can be reported within the successive water year.

3.2 Ground Water Assessment Unit

This methodology recommends aquifer wise ground water resource assessment. An essential requirement for this is to demarcate lateral as well as vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for ground water resource estimation if the principal aquifer is other than alluvium. Ground water resources worked out on watershed as a unit, may be apportioned and presented on administrative units (block/ taluka/ mandal/ firka). This would facilitate local administration in planning of ground water management programmes. Areas occupied by unconsolidated sediments (alluvial deposits, aeolian deposits, coastal deposits etc.) usually have flat topography and demarcation of watershed boundaries may not be possible in such areas. Until Aquifer Geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/ mandals/ firkas in soft rock areas may be continued. The ground water resources assessment was carried out based on the guidelines of Ministry of Water Resources, RD & GR which broadly follows the methodology recommended by Ground Water Resources Estimation Committee, 2015. The salient features of the methodology are enumerated in the following paragraphs.

The ground water recharge is estimated season-wise both for monsoon season and non- monsoon season separately. The following recharge and discharge components are assessed in the resource assessment - recharge from rainfall, recharge from canal, return flow from irrigation, recharge from tanks and ponds and recharge from water conservation structures and discharge through ground water draft. The ground water resources of any assessment unit is the sum of the total ground water availability in the principal aquifer (mostly unconfined aquifer) and the total ground water availability of semi-confined and confined aquifers existing in that assessment unit. The total ground water availability of any aquifer is the sum of Dynamic ground water resources and the In-storage or Static resources of the aquifer.

3.3 Ground Water Assessment of Unconfined Aquifer

As mentioned earlier, assessment of ground water includes assessment of dynamic and in- storage ground water resources. The development planning should mainly depend on dynamic resource only as it gets replenished every year. Changes in static or in-storage resources reflect impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

3.3.1 Dynamic Ground Water Resources

The methodology for ground water resources estimation is based on the principle of water balance as given below –

Inflow – Outflow = Change in Storage (of an aquifer) **1**

Equation 1 can be further elaborated as -

$$\Delta S = R_{RF} + R_{STR} + R_{C} + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \qquad 2$$

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR}- Recharge from stream channels

R_c – Recharge from canals

R_{SWI} – Recharge from surface water irrigation

R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from Tanks and Ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical flow across the aquifer system

LF- Lateral flow along the aquifer system (through flow)

GE-Ground Water Extraction

T- Transpiration

E- Evaporation

B-Base flow

It is preferred that all the components of water balance equation should be estimated in an assessment unit. The present status of database available with Government and non- government agencies is not adequate to carry out detailed ground water budgeting in most of the assessment units. Therefore, it is proposed that at present the water budget may be restricted to the major components only taking into consideration certain reasonable assumptions. The estimation is to be carried out using lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

3.3.2 Rainfall Recharge

It is recommended that ground water recharge should be estimated on ground water level fluctuation and specific yield approach since this method takes into account the response of ground water levels to ground water input and output components. This, however, requires adequately spaced representative water level measurement for a sufficiently long period. It is proposed that there should be at least three spatially well distributed observation wells in the assessment unit, or one observation well per 100 sq. Km. Water level data should also be available for a minimum period of 5 years (preferably 10years), along with corresponding rainfall data. Regarding frequency of water level data, three water level readings during pre and post monsoon seasons and in the month of January/ May preferably in successive years, are the minimum requirements. It would be ideal to have monthly water level measurements to record the peak rise and maximum fall in the ground water levels. In units or subareas where, adequate data on ground water level fluctuations are not available as specified above, ground water recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season may be estimated using rainfall infiltration factor method only.

3.3.3 Ground water level fluctuation method

The ground water level fluctuation method is to be used for assessment of rainfall recharge in the monsoon season. The ground water balance equation in non-command areas is given by

$$\Delta S = R_{RF}+R_{STR}+R_{SWI}+R_{GWI}+R_{TP}+R_{WCS}\pm VF \pm LF - GE - T - E - B \qquad 3$$

Where,

ΔS – Change in storage

R_{RF} – Rainfall recharge

R_{STR}- Recharge from stream channels

R_{SWI} – Recharge from surface water irrigation (Lift Irrigation)

R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from tank and ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical flow across the aquifer system

LF- Lateral flow along the aquifer system (through flow)

GE-Ground water Extraction

T- Transpiration

E- Evaporation

B-Base flow

Whereas the water balance equation in command area will have another term Recharge due to canals (R_C) and the equation will be as follows:

$$\Delta S = R_{RF}+R_{STR}+R_{C}+R_{SWI}+R_{GWI}+R_{T}+R_{WCS}\pm VF \pm LF - GE - T - E - B \qquad 4$$

A couple of important observations in the context of water level measurement must be followed. It is important to bear in mind that while estimating the quantum of ground water extraction, the depth from which ground water is being extracted should be considered, and certain limit should be fixed. First, by estimating recharge by Water Level Fluctuation method, rise in water level (pre to post monsoon Water Level observed in a dug well) is considered and in estimating the draft from dug wells and bore wells (shallow and deep) drop in water level is considered. One should consider only the draft from the same aquifer for which the resource is being estimated.

The change in storage can be estimated using the following equation:

$$\Delta S = \Delta h * A * S_Y \qquad 5$$

Where

ΔS – Change in storage

Δh - rise in water level in the monsoon season A - area for computation of recharge

Sy - Specific Yield

Substituting the expression in equation 5 for storage increase ΔS in terms of water level fluctuation and specific yield, the equations 3 and 4 becomes,

$$\mathbf{R_{RF} = h \times Sy \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \quad \mathbf{6}$$

$$\mathbf{R_{RF} = h \times Sy \times A - R_{C} - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \quad \mathbf{7}$$

The recharge calculated from equation 6 in case of non-command sub units and equation 7 in case of command sub units and poor ground water quality sub units gives the rainfall recharge for the particular monsoon season. However, it may be noted that in case base flow/ recharge from stream and through flow have not been estimated, the same may be assumed to be zero.

The rainfall recharge obtained by using equation 6 and equation 7 provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalized for the normal monsoon season rainfall as per the procedure indicated below.

Normalization of Rainfall Recharge

Let Ri be the rainfall recharge and ri be the associated rainfall. The subscript i takes values 1 to N where N is number of years data is available which is at least 5. The rainfall recharge, Ri is obtained as per equation 6 and equation 7 depending on the sub unit for which the normalization is being done.

$$\mathbf{R_i = h \times Sy \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \quad \mathbf{8}$$

$$\mathbf{R_i = h \times Sy \times A - R_{C} - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B} \quad \mathbf{9}$$

where,

Ri= Rainfall recharge estimated in the monsoon season for the i^{th} particular year

h= Rise in ground water level in the monsoon season for the i^{th} particular year

Sy =Specific yield

A= Area for computation of recharge

GE = Ground water extraction in monsoon season for the i^{th} particular year

B= Base flow the monsoon season for the i^{th} particular year

R_C = Recharge from canals in the monsoon season for i^{th} particular year

R_{STR}= Recharge from stream channels in the monsoon season for i^{th} particular year

R_{SWI} = Recharge from surface water irrigation including lift irrigation in the monsoon season for the i^{th} particular year

R_{GWI} = Recharge from groundwater irrigation in the monsoon season for the i^{th} particular year

R_{WCS} =Recharge from water conservation structures in the monsoon season for the i^{th} particular year

R_{TP}= Recharge from tanks and ponds in the monsoon season for the i^{th} particular year

LF= Recharge through Lateral flow/ Through flow across assessment unit boundary in the monsoon season for the i^{th} particular year

VF – Vertical flow across the aquifer system in the monsoon season for the i^{th} particular year

T- Transpiration in the monsoon season for the i^{th} particular year E- Evaporation in the monsoon season for the i^{th} particular year

After the pairs of data on Ri and ri have been obtained as described above, a normalization procedure is to be carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let r(normal) be the normal monsoon season rainfall obtained on the basis of recent 30 to 50 years of monsoon season rainfall data. Two methods are possible for the normalization procedure.

The first method is based on a linear relationship between recharge and rainfall of the form

$$\mathbf{R = ar} \qquad \mathbf{10}$$

where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

The computational procedure to be followed in the first method is as given below:

$$Rrf(normal) = \frac{\sum_{i=1}^{N}\left[R_i \times \frac{r(normal)}{r_i}\right]}{N} \qquad \mathbf{11}$$

Where,

R_{rf} (normal) - Normalized Rainfall Recharge in the monsoon season.

R_i - Rainfall Recharge in the monsoon season for the i^{th} year.

r(normal) - Normal monsoon Season rainfall.

r_i - Rain fall in the monsoon season for the i^{th} year.

N - No, of years data is available.

The second method is also based on a linear relation between recharge and rainfall.
However, this linear relationship is of the form,

$$\mathbf{R = ar+b} \qquad \mathbf{12}$$

where,
R = Rainfall recharge during monsoon season

r = Monsoon season rainfall
a and b = constants.

The two constants ‘a’ and ‘b’ in the above equation are obtained through a linear regression analysis. The computational procedure to be followed in the second method is as given below:

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2} \qquad \mathbf{13}$$

$$b = \frac{S_2 - aS_1}{N} \qquad \mathbf{14}$$

Where

$$S_1 = \sum_{i=1}^{N} r_i \qquad S_2 = \sum_{i=1}^{N} R_i \qquad S_3 = \sum_{i=1}^{N} r_i^2 \qquad S_4 = \sum_{i=1}^{N} r_i R_i$$

The rainfall recharge during monsoon season for normal monsoon rainfall condition is computed as below:

$$\mathbf{R_{rf}\ (normal) = a \times r(normal) + b} \qquad \mathbf{15}$$

3.3.4 Rainfall Infiltration Factor method

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of ground water level. However the ground water extraction estimation included in the computation of rainfall recharge using Water Level Fluctuation approach is often subject to uncertainties. Therefore, it is recommended to compare the rainfall recharge obtained from Water Level Fluctuation approach with that estimated using Rainfall Infiltration Factor Method.

Recharge from rainfall is estimated by using the following relationship -

$$\mathbf{R_{rf} = RFIF * A * (R - a)/1000} \qquad \mathbf{16}$$

Where,

R_{rf} = Rainfall recharge in ham A = Area in Hectares

RFIF = Rainfall Infiltration Factor R = Rainfall in mm

a = Minimum threshold value above which rainfall induces ground water recharge in mm

The relationship between rainfall and ground water recharge is a complex phenomenon depending on several factors like runoff coefficient, moisture balance, hydraulic conductivity and Storativity/ Specific yield of the aquifer etc. In this report, certain assumptions have been adopted for computation of Rainfall recharge factor. These assumptions may be replaced with actual data in case such area specific studies are available. At the same time, it is important to bring in elements of rainfall distribution and variability into sharpening the estimates of precipitation. Average rainfall data from nearby rain gauge stations may be considered for the Ground water assessment unit and the average rainfall may be estimated by the Theisen polygon or isohyet methods. Alternatively other advanced methods may also be used.

The threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is to be considered while estimating ground water recharge using rainfall infiltration factor. The minimum threshold limit is in accordance with the relation shown in equation 16 and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rains are too high to infiltrate the ground and they will only contribute to surface runoff. It is suggested that 10% of Normal annual rainfall be taken as Minimum Rainfall Threshold and 3000 mm as Maximum Rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall is to be deducted from the monsoon rainfall and balance rainfall would be considered for computation of rainfall recharge. The same recharge factor may be used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall may be taken as zero, if the normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall. In using the method based on the specified norms, recharge due to both monsoon and non-monsoon rainfall may be estimated for normal rainfall, based on recent 30 to 50 years of data.

3.3.5 Percent Deviation

After computing the rainfall recharge for normal monsoon season rainfall using the water table fluctuation method and Rainfall Infiltration Factor method these two estimates have to be compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the former is computed as

$$PD = \frac{Rrf\,(normal, wtfm) - Rrf\,(normal, rifm)}{Rrf\,(normal, wtfm)} X100 \qquad \textbf{17}$$

where,

Rrf (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the water level fluctuation method

Rrf (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

The rainfall recharge for normal monsoon season rainfall is finally adopted as per the criteria given below:

- If PD is greater than or equal to -20%, and less than or equal to +20%,Rrf (normal) is taken as the value estimated by the water level fluctuation method.
- If PD is less than -20%, Rrf (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.
- If PD is greater than +20%, Rrf (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

3.3.6 Recharge from other Sources

Recharge from other sources constitute recharges from canals, surface water irrigation, ground water irrigation, tanks and ponds and water conservation structures in command areas where as in non-command areas the recharge due to surface water irrigation, ground water irrigation, tanks and ponds and water conservation structures are possible.

Recharge from Canals: Recharge due to canals is to be estimated based on the following formula:

$$\mathbf{R_C = WA * SF * Days} \qquad \textbf{18}$$

Where:

R_C= Recharge from Canals WA=Wetted Area

SF= Seepage Factor

Days= Number of Canal Running Days.

3.3.7 Recharge from Surface Water Irrigation:

Recharge due to applied surface water irrigation, either by means of canal outlets or by lift irrigation schemes is to be estimated based on the following formula:

$$R_{SWI} = AD*Days*RFF \quad (19)$$

Where:

R_{SWI} = Recharge due to applied surface water irrigation

AD= Average Discharge

Days=Number of days water is discharged to the Fields

RFF= Return Flow Factor

3.3.8 Recharge from Ground Water Irrigation:

Recharge due to applied ground water irrigation is to be estimated based on the following formula:

$$R_{GWI} = GE_{IRR}*RFF \quad (20)$$

Where:

R_{GWI} = Recharge due to applied ground water irrigation GE_{IRR}= Ground Water Extraction for Irrigation

RFF= Return Flow Factor

3.3.9 Recharge due to Tanks and Ponds:

Recharge due to Tanks and Ponds is to be estimated based on the following formula:

$$R_{TP} = AWSA*RF \quad (21)$$

Where:

R_{TP} = Recharge due to Tanks and Ponds

AWSA= Average Water Spread Area

RF= Recharge Factor

3.3.10 Recharge due to Water Conservation Structures:

Recharge due to Water Conservation Structures is to be estimated based on the following formula:

$$\mathbf{R_{WCS} = GS * RF} \qquad \mathbf{22}$$

Where:

R_{WCS} = Recharge due to Water Conservation Structures

GS= Gross Storage = Storage Capacity multiplied by number of fillings.

RF= Recharge Factor

3.4 Lateral flow along the aquifer system (Through flow)

In equations 6 and 7, if the area under consideration is a watershed, the lateral flow across boundaries can be considered as zero in case such estimates are not available. If there is inflow and outflow across the boundary, theoretically, the net inflow may be calculated using Darcy law, by delineating the inflow and outflow sections of the boundary. Besides such delineation, the calculation also requires estimate of transmissivity and hydraulic gradient across the inflow and outflow sections. These calculations are most conveniently done in a computer model. It is recommended to initiate regional scale modelling with well-defined flow boundaries. Once the modelling is complete, the lateral through flows (LF) across boundaries for any assessment unit can be obtained from the model. In case Lateral Flow is calculated using computer model, the same should be included in the water balance equation.

3.5 Base flow and Stream Recharge

If stream gauge stations are located in the assessment unit, the base flow and recharge from streams can be computed using Stream Hydrograph Separation method, Numerical Modelling and Analytical solutions. If the assessment unit is a watershed, a single stream monitoring station at the mouth of the watershed can provide the required data for the calculation of base flow. Any other information on local-level base flows such as those collected by research centers, educational institutes or NGOs may also be used to improve the estimates on base flows.

Base flow separation methods can be divided into two main types: non-tracer-based and tracer-based separation methods. Non-tracer methods include Stream hydrograph analysis, water balance method and numerical ground water modelling techniques. Digital filters are available for separating base flow component of the stream hydrograph.

Hydro-chemical tracers and environmental isotope methods also use hydrograph separation techniques based on mass balance approach. Stream recharge can also be estimated using the above techniques.

Base flow assessment and Stream recharge should be carried out in consultation with Central Water Commission in order to avoid any duplicity in the estimation of total water availability in a river basin.

3.6 Vertical Flow from Hydraulically Connected Aquifers

This can be estimated provided aquifer geometry and aquifer parameters are known. This can be calculated using the Darcy’s law if the hydraulic heads in both aquifers and the hydraulic conductivity and thickness of the aquitard separating both the aquifers are known. Ground water flow modelling is an important tool to estimate such flows. As envisaged in this report regional scale modelling studies will help in refining vertical flow estimates.

3.7 Evaporation and Transpiration

Evaporation can be estimated for the aquifer in the assessment unit if water levels in the aquifer are within the capillary zone. It is recommended to compute the evaporation through field studies. If field studies are not possible, for areas with water levels within 1.0 mbgl, evaporation can be estimated using the evaporation rates available for other adjoining areas. If depth to water level is more than 1.0m bgl, the evaporation losses from the aquifer should be taken as zero.

Transpiration through vegetation can be estimated if water levels in the aquifer are within the maximum root zone of the local vegetation. It is recommended to compute the transpiration through field studies. Even though it varies from place to place depending on type of soil and vegetation, in the absence of field studies the following estimation can be followed. If water levels are within 3.5m bgl, transpiration can be estimated using the transpiration rates available for other areas. If it is greater than 3.5m bgl, the transpiration should be taken as zero.

For estimating evapotranspiration, field tools like Lysimeters can be used to estimate actual evapotranspiration. Usually agricultural universities and IMD carry out lysimeter experiments and archive the evapotranspiration data. Remote sensing based techniques like SEBAL (Surface Energy Balance Algorithm for Land) can be used for estimation of actual evapotranspiration. Assessing offices may apply available lysimeter data or other techniques for estimation of evapotranspiration. In case where such data is not available, evapotranspiration losses can be empirically estimated from PET data provided by IMD.

3.8 Recharge during Monsoon Season

The sum of normalized monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into the sub unit and stream inflows during monsoon season is the total recharge during monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

3.9 Recharge during Non-Monsoon Season

The rainfall recharge during non-monsoon season is estimated using Rainfall Infiltration factor Method only when the non-monsoon season rainfall is more than 10% of normal annual rainfall. The sum of non-monsoon rainfall recharge and the recharge from other sources and lateral and vertical flows into the sub unit and stream inflows during non-monsoon season is the total recharge during non-monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

3.10 Total Annual Ground Water Recharge

The sum of the recharge during monsoon and non-monsoon seasons is the total annual ground water recharge for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

3.11 Annual Extractable Ground Water Recharge (EGR)

The Total Annual Ground Water Recharge cannot be utilized for human consumption, since ecological commitments need to be fulfilled, before the extractable resources is defined. The National Water Policy, 2012 stresses that the ecological flow of rivers should be maintained. Therefore, Ground water base flow contribution limited to the ecological flow of the river should be determined which will be deducted from Annual Ground Water Recharge to determine Annual Extractable Ground Water Resources (EGR). The ecological flows of the rivers are to be determined in consultation with Central Water Commission and other concerned river basin agencies.

In case base flow contribution to the ecological flow of rivers is not determined then following assumption is to be followed. In the water level fluctuation method, a significant

portion of base flow is already accounted for by taking the post monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, present practice (GEC

1997) of allocation of unaccountable natural discharges to 5% or 10% of annual recharge may be retained. If the rainfall recharge is assessed using water level fluctuation method this will be 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, it will be 10% of the annual recharge. The balance will account for Annual Extractable Ground Water Resources (EGR).

3.12 Estimation of Ground Water Extraction

Groundwater draft or extraction is to be assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND} \quad \mathbf{23}$$

Where,
GE_{ALL}=Ground water extraction for all uses GE_{IRR}=Ground water extraction for irrigation

GE_{DOM} =Ground water extraction for domestic uses GE_{IND} = Ground water extraction for industrial uses

3.12.1 Ground Water Extraction for Irrigation (GE_{IRR}):

The single largest component of the groundwater balance equation in large regions of India is the groundwater extraction and, the precise estimation of ground water extraction is riddled with uncertainties. Therefore, it is recommended that at least two of the three methods for estimation of ground water extraction may be employed in each assessment sub unit. The methods for estimation of ground water extraction are as follows.

Unit Draft Method: – In this method, season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (e.g. Dug well, dug cum bore well, shallow tube well, deep tube well, bore well etc.) is multiplied with the number of wells of that particular type to obtain season-wise ground water extraction by that particular structure. This method is being widely practiced in the country. There are several sources which maintain records on well census. These include Minor Irrigation Census conducted by MoWR, RD, GR, Government of India, and data maintained at the Tehsil level. It is recommended that a single source of well census should be maintained for resources computation at all India level. Minor Irrigation Census of MoWR, RD, GR would be the preferred option.

Crop Water Requirement Method: – For each crop, the season-wise net irrigation water requirement is determined. This is then multiplied with the area irrigated by ground water abstraction structures.

The database on crop area is obtained from Revenue records in Tehsil office, Agriculture Census and also by using Remote Sensing techniques.

Power Consumption Method: – Ground water extraction for unit power consumption (electric) is determined. Extraction per unit power consumption is then multiplied with number of units of power consumed for agricultural pump sets to obtain total ground water extraction for irrigation. Direct metering of ground water draft in select irrigation and domestic wells and in all wells established for industrial purpose may be initiated. Enforcing fitting of water meters and recording draft in all govt. funded wells could also be a feasible option. The unit drafts obtained from these sample surveys can be used to assess ground water extraction. In addition to metering, dedicated field sample surveys (instantaneous discharge measurements) can also be taken up.

3.12.2 Ground Water Extraction for Domestic Use (GE_{DOM}):

There are several methods for estimation of extraction for domestic use (GE_{DOM}). Some of the commonly adopted methods are described here.

Unit Draft Method: – In this method, unit draft of each type of well is multiplied by the number of wells used for domestic purpose to obtain the domestic ground water draft.

Consumptive Use Method: – In this method, population is multiplied with per capita consumption usually expressed in liter per capita per day (lpcd). It can be expressed using following equation.

$$GE_{DOM} = \text{Population} \times \text{Consumptive Requirement} \times Lg$$

Where,

Lg = Fractional Load on Ground Water for Domestic Water Supply

The Load on Ground water can be obtained from the Information based on Civic water supply agencies in urban areas.

3.12.3 Ground water Extraction for Industrial use (GE_{IND}):

The commonly adopted methods for estimating the extraction for industrial use are as below:

Unit Draft Method: - In this method, unit draft of each type of well is multiplied by the number of wells used for industrial purpose to obtain the industrial ground water extraction.

Consumptive Use Pattern Method: – In this method, water consumption of different industrial units are determined. Number of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water draft for industrial use.

$$GE_{IND} = \text{Number of industrial units X Unit Water Consumption X Lg} \qquad \textbf{25}$$

Where,

Lg = Fractional load on ground water for industrial water supply

The load on Ground water for Industrial water supply can be obtained from water supply agencies in the Industrial belt. Other important sources of data on ground water extraction for industrial uses are - Central Ground Water Authority, State Ground Water Authority, National Green Tribunal and other Environmental Regulatory Authorities.

Ground water extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, ground water extraction obtained by different methods may vary widely. In such cases, the value matching the field situation should be considered. The storage depletion during a season where other recharges are negligible can be taken as ground water extraction during that particular period.

3.13 Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$\text{Stage of Ground Water Extraction (\%)} = \frac{\text{Existing gross ground water extraction for all uses}}{\text{Annual Extractable Ground Water Resources}} \text{X } 100 \qquad \textbf{26}$$

The existing gross ground water extraction for all uses refers to the total of existing gross ground water extraction for irrigation and all other purposes. The stage of ground water extraction should be obtained separately for command areas, non-command areas and poor ground water quality areas.

3.14 Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. The estimation of ground water extraction is likely to be associated with considerable uncertainties as it is based on indirect assessment using factors such as electricity consumption, well census and area irrigated from ground water. The denominator in equation 26, namely Annual Extractable Ground

Water Resources also has uncertainties due to limitations in the assessment methodology, as well as uncertainties in the data. In view of this, it is desirable to validate the „Stage of Ground Water Extraction" with long term trend of ground water levels.

Long term Water Level trends are to be prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. The Water level Trend would be average water level trend as obtained from the different observation wells in the area.

In interpreting the long-term trend of ground water levels, the following points may be kept in view. If the pre and post monsoon water levels show a fairly stable trend, it does not necessarily mean that there is no scope for further ground water development. Such a trend indicates that there is a balance between recharge, extraction and natural discharge in the unit. However, further ground water development may be possible, which may result in a new stable trend at a lower ground water level with associated reduced natural discharge.

If the ground water resource assessment and the trend of long-term water levels contradict each other, this anomalous situation requires a review of the ground water resource computation, as well as the reliability of water level data. The mismatch conditions are enumerated below.

SOGWE	**Ground Water level trend**	**Remarks**
≤70%	Decline trend in both pre-monsoon and post-monsoon	Not acceptable and needs reassessment
>100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs reassessment

In case, the category does not match with the water level trend given above, a 'reassessment" should be attempted. If the mismatch persists even after reassessment, the sub unit may be categorized based on Stage of Ground Water Extraction of the reassessment. However, the sub unit should be flagged for strengthening of observation well network and parameter estimation.

3.15 Categorization of Assessment Units

As emphasized in the National Water Policy, 2012, a convergence of Quantity and Quality of ground water resources is required while assessing the ground water status in an assessment unit. Therefore, it is recommended to separate estimation of resources where water quality is beyond permissible limits for the parameter salinity.

3.15.1 Categorization of Assessment Units Based on Quantity:

The categorization based on status of ground water quantity is defined by Stage of Ground Water extraction as given below:

Stage of Ground Water Extraction	Category
≤70%	Safe
> 70%and ≤90%	Semi-Critical
> 90%and ≤100%	Critical
> 100%	Over Exploited

In addition to this Category every assessment sub unit should be tagged with potentiality tag indicating its ground water potentiality viz. Poor Potential (Unit Recharge <0.025m), Moderately Potential (Unit Recharge in between 0.025 and 0.15m) and Highly Potential (Unit Recharge > 0.15m).

3.15.2 Categorization of Assessment Units Based on Quality

GEC 1997 proposed categorization of assessment units based on ground water extraction only. To adequately inform management decisions, quality of ground water is also an essential criterion. The Committee deliberated upon the possible ways of categorizing the assessment units based on ground water quality in the assessment units. It was realized that based on the available water quality monitoring mechanism and available database on ground water quality it may not be possible to categorize the assessment units in terms of the extent of quality hazard. As a trade-off, the Committee recommends that each assessment unit, in addition to the Quantity based categorization (safe, semi-critical, critical and over-exploited) should bear a quality hazard identifier. Such quality hazards are to be based on available ground water monitoring data of State Ground Water Departments and/or Central Ground Water Board. If any of the three quality hazards in terms of Arsenic, Fluoride and Salinity are encountered in the assessment sub unit in mappable units, the assessment sub unit may be tagged with the particular Quality hazard.

3.16 Allocation of Ground Water Resource for Utilization

The Annual Extractable Ground Water Resources are to be apportioned between domestic, industrial and irrigation uses. Among these, as per the National Water Policy, requirement for domestic water supply is to be accorded priority. This requirement has to be based on population as projected to the year 2025, per capita requirement of water for domestic use, and relative load on ground water for urban and rural water supply. The estimate of allocation for domestic water requirement may vary for one sub unit to the other in different states. In situations where adequate data is not available to make this estimate, the following empirical relation is recommended.

$$\mathbf{Alloc = 22 \times N \times L_g \text{ mm per year}} \qquad \mathbf{27}$$

Where

Alloc= Allocation for domestic water requirement

N = population density in the unit in thousands per sq. km.

L_g = fractional load on ground water for domestic and industrial water supply (<_ 1.0)

In deriving equation 27, it is assumed that the requirement of water for domestic use is 60 lpd per head. The equation can be suitably modified in case per capita requirement is different. If by chance, the estimation of projected allocation for future domestic needs is less than the current domestic extraction due to any reason, the allocation must be equal to the present day extraction. It can never be less than the present day extraction as it is unrealistic.

3.17 Net Annual Ground Water Availability for Future Use

The water available for future use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual extractable Ground Water Recharge. The resulting ground water potential is termed as the net annual ground water availability for future use. The Net annual ground water availability for future use should be calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the ground water available for future use can never be negative. If it becomes negative, the future allocation of Domestic needs can be reduced to current extraction for domestic use. Even then if it is still negative, then the ground water available for future uses will be zero.

3.18 Additional Potential Resources under Specific Conditions

3.18.1 Potential Resource Due to Spring Discharge:

Spring discharge constitutes an additional source of ground water in hilly areas which emerges at the places where ground water level cuts the surface topography. The spring discharge is equal to the ground water recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub- surface flow. Thus Spring Discharge is a form of "Annual Extractable Ground Water Recharge‟. It is a renewable resource, though not to be used for Categorization. Spring discharge measurement is to be carried out by volumetric measurement of discharge of the springs. Spring discharges multiplied with time in days of each season will give the quantum of spring resources available during that season. The committee recommends that in hilly areas with substantial potential of spring discharges, the discharge measurement should be made at least 4 times a year in parity with the existing water level monitoring schedule.

Potential ground water resource due to springs = Q x No of days **28**

Where

Q = Spring Discharge

No of days= No of days spring yields.

3.18.2 Potential Resource in Waterlogged and Shallow Water Table Areas:

The quantum of water available for development is usually restricted to long term average recharge or in other words "Dynamic Resources". But the resource calculated by water level fluctuation approach is likely to lead to under-estimation of recharge in areas with shallow water table, particularly in discharge areas of sub-basin/ watershed/ block/ taluka and waterlogged areas. In such cases rejected recharge may be substantial and water level fluctuations are subdued resulting in under-estimation of recharge component. It is therefore, desirable that the ground water reservoir should be drawn to optimum limit before the onset of monsoon, to provide adequate scope for its recharge during the following monsoon period.

In the area where the ground water level is less than 5m below ground level or in waterlogged areas, the resources up to 5m below ground level are potential and would be available for development in addition to the annual recharge in the area. It is therefore recommended that in such areas, ground water resources may be estimated up to 5m bgl only assuming that where water level is less than 5m bgl, the same could be depressed by pumping to create space to receive recharge from natural resources. It is further evident that these potential recharges would be available mostly in the shallow water table areas which would have to be demarcated in each sub-basin/ watershed/ block/ taluka/ mandal.

The computation of potential resource to ground water reservoir can be done by adopting the following equation:

Potential ground water resource in shallow water table areas = (5-D) x A x S_Y **29**

Where

D= Depth to water table below ground surface in pre-monsoon period in shallow aquifers.

A= Area of shallow water table Zone

S_Y = Specific Yield

The planning of future minor irrigation works in the waterlogged and shallow water table areas as indicated above should be done in such a way that there should be no long term adverse effects of lowering of water table up to 5m and the water level does not decline much below 5m in such areas. The behavior of water table in the adjoining area which is not water logged should be taken as a bench mark for development purposes.

This potential recharge to ground water is available only after depression of water level up to 5m bgl. This is not an annual resource and should be recommended for development on a very cautious approach so that it does not adversely affect the ground water potentials in the overall area.

3.18.3 Potential Resource in Flood Prone Areas:

Ground water recharge from a flood plain is mainly the function of the following parameters-

- Areal extent of flood plain
- Retention period of flood
- Type of sub-soil strata and silt charge in the river water which gets deposited and controls seepage

Since collection of data on all these factors is time taking and difficult, in the meantime, the potential recharge from flood plain may be estimated on the same norms as for ponds, tanks and lakes. This has to be calculated over the water spread area and only for the retention period using the following formula.

Potential ground water resource in Flood Prone Areas = 1.4 x N x A/1000 30

Where

N = No of Days Water is Retained in the Area A = Flood Prone Area

3.19 Apportioning of Ground Water Assessment from Watershed to Development Unit:

Where the assessment unit is a watershed, there is a need to convert the ground water assessment in terms of an administrative unit such as block/ taluka/ mandal. This may be done as follows.

A block may comprise of one or more watersheds, in part or full. First, the ground water assessment in the subareas, command, non-command and poor ground water quality areas of the watershed may be converted into depth unit (mm), by dividing the annual recharge by the respective area. The contribution of this subarea of the watershed to the block, is now calculated by multiplying this depth with the area in the block occupied by this sub-area. This procedure must be followed to calculate the contribution from the sub-areas of all watersheds occurring in the block, to work out the total ground water resource of the block.

The total ground water resource of the block should be presented separately for each type of sub-area, namely for command areas, non-command areas and poor ground water quality areas, as in the case of the individual watersheds.

3.20 Assessment of In-Storage Ground Water Resources or Static Ground Water Resources

The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. Presently there is no fine demarcation to distinguish the dynamic resources from the static resources. While water table hydrograph could be an indicator to distinguish dynamic resources, at times it is difficult when water tables are deep. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage.

Assessment of In-storage ground water resources has assumed greater significance in the present context, when an estimation of Storage Depletion needs to be carried out in Over- exploited areas. Recently Remote Sensing techniques have been used in GRACE studies, to estimate the depletion of Ground Water Resources in North West India. Such estimation presents larger scale scenario. More precise estimation of ground water depletion in the over-exploited area based on actual field data can be obtained by estimating the Change in In-storage during successive assessments. Thus In-storage computation is necessary not only for estimation of emergency storage available for utilization in case of natural extremities (like drought) but also for an assessment of storage depletion in over-exploited areas for sensitizing stakeholders about the damage done to the environment.

The computation of the static or in-storage ground water resources may be done after delineating the aquifer thickness and specific yield of the aquifer material. The computations can be done as follows: -

$$\mathbf{SGWR = A * (Z_2 - Z_1) * S_Y} \qquad \mathbf{31}$$

Where,

SGWR = Static or in-storage Ground Water Resources

A = Area of the Assessment Unit

Z_2 = Bottom of Unconfined Aquifer

Z_1 = Pre-monsoon water level

S_Y = Specific Yield in the In storage Zone

3.21 Assessment of Total Ground Water Availability in Unconfined Aquifer

The sum of Annual Exploitable Ground Water Recharge and the In storage ground water resources of an unconfined aquifer is the Total Ground Water Availability of that aquifer.

3.22 Ground Water Assessment of Confined Aquifer System

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. If the piezometric surface of the confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs, the coefficient of storage is no longer related to the elasticity of the aquifer but to its specific yield. In view of the small amounts of water released from storage in the confined aquifers, large scale pumpage from confined aquifers may cause decline in piezometric levels amounting to over a hundred meter and subsidence of land surface posing serious geotectonically problems.

It is recommended to use ground water storage approach to assess the ground water resources of the confined aquifers. The co-efficient of storage or storativity of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in head. Hence the quantity of water added to or released from the aquifer (V) can be calculated as follows

$$\Delta V = S \Delta h \qquad 32$$

If the areal extent of the confined aquifer is A then the total quantity of water added to or released from the entire aquifer is

$$Q = A \Delta V = SA \Delta h \qquad 33$$

Where

Q = Quantity of water confined aquifer can release (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

Most of the storage in confined aquifer is associated with compressibility of the aquifer matrix and compressibility of water. Once the piezometric head reaches below the top confining bed, it behaves like an unconfined aquifer and directly dewaters the aquifer and there is a possibility of damage to the aquifer as well as topography. Hence ground water potential of a confined aquifer is nothing but the water available for use without damaging the aquifer. Hence the resources available under pressure are only considered as the ground water potential. The quantity of water released in confined aquifer due to change in pressure can be computed between piezometric head (h_t) at any given time 't' and the bottom of the top confining layer (h_o) by using the following equation.

$$Q_p = SA\Delta h = SA (h_t - h_0) \qquad 34$$

If any development activity is started in the confined aquifer, then there is a need to assess the dynamic as well as in storage resources of the confined aquifer. To assess the ground water resources of the confined aquifer, there is a need to have sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also needed.

3.22.1 Dynamic Ground Water Resources of Confined Aquifer

To assess the dynamic ground water resources the following equation can be used with the pre and post monsoon piezometric heads of the particular aquifer.

$$Q_D = SA\Delta h = SA\,(h_{POST} - h_{PRE}) \qquad 35$$

Where

Q_D = Dynamic Ground Water Resource of Confined Aquifer (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

h_{post} =Piezometric head during post-monsoon period (m amsl)

h_{PRE} = Piezometric head during pre-monsoon period (m amsl)

3.22.2 In storage Ground Water Resources of Confined Aquifer

For assessing the in storage ground water potential of a confined aquifer, one has to compute the resources between the pre monsoon piezometric head and bottom of the top confining layer. That can be assessed using the following formula:

$$Q_I = SA\Delta h = SA\,(h_{PRE} - h_0) \qquad 36$$

Where

Q_I =In storage Ground Water Resource of Confined Aquifer (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

h_0 = Bottom level of the top confining layer (m amsl)

h_{PRE} = Piezometric head during pre-monsoon period (m amsl)

If the confined aquifer is not being exploited for any purpose, the dynamic and static resources of the confined aquifer need not be estimated separately. Instead the in storage of the aquifer can be computed using the following formula.

$$\mathbf{Q_p = SA\Delta h = SA\,(h_{POST} - h_0)} \qquad \mathbf{37}$$

Where

Q_p = In storage Ground Water Resource of the confined aquifer or the Quantity of water under pressure (m^3)

S = Storativity

A = Areal extent of the confined aquifer (m^2)

Δh = Change in Piezometric head (m)

H_{POST} = Piezometric head during post-monsoon period (m amsl) h_0 = Bottom of the Top Confining Layer (m amsl)

The calculated resource includes small amount of dynamic resource of the confined aquifer also, which replenishes every year. But to make it simpler this was also computed as part of the static or in-storage resource of the confined aquifer.

CHAPTER-4 PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT

In the present assessment for the UT, the data source and collection for each of the data element required as per GEC 2015 methodology is detailed as under:

- The basic data including area, land use have been collected from Census handbook.
- Data on rainfall data has been collected from the Meteorological Department (IMD).
- The data pertaining to tube wells for agriculture, domestic and industries along with their draft has been collected from the Engineering Department, U T Administration and Municipal Cooperation, Chandigarh.
- Data for population and its projection has been taken from Census handbook. Domestic draft has been calculated on population basis. Population figures have been taken as person.
- The Agricultural data has been taken from the Department of Agriculture, Chandigarh UT.
- Data on Depth to water level, ground water quality, aquifer parameters have been availed from Central Groundwater Board.
- Data pertaining to Urban water supply and Tertiary treatment of STP provided by Municipal Cooperation, Chandigarh.
- Data on water conservation structure provided by UT Administration and CGWB.
- Data for ponds supplied by Municipal Cooperation, Chandigarh.

It is pertinent to note that INGRES software has been used for computation of data and no changes in the original methodology proposed by GEC have been made during the present assessment.

The norms used in the present assessment for computation of return flow factor for irrigation water by ground water irrigation, rainfall infiltration factor, specific yield etc. have been taken as per GEC specified norms. As regards to the unit well draft, the figures used in computation are based on the actual field data.

CHAPTER-5 COMPUTATION OF GROUND WATER RESOURCES ESTIMATION

5.1 Salient Features of Dynamic Ground Water Resources Assessment

BRIEF SUMMARY OF DYNAMIC RESOURCES OF CHANDIGARH UT

Type of Assessment Units	Blocks
No. of Assessment Units (Blocks) taken for Study	01
Years of Collection of Data (10 years)	2014-2023
No. of Over-Exploited Blocks	Nil
No. of Critical Blocks	Nil
No. of Semi-Critical Blocks	Nil
No. of Safe Blocks	**01**

Chandigarh (UT) has very small area around 114 Sq. km and whole UT has been taken as an assessment unit. Groundwater level data of the period 2014-23 has been used for estimation and long-term trends for categorization.

The depth to water level in shallow aquifers ranges from 6.29 to 9.3 mbgl during pre-monsoon of 2013-22 and 6.34 to 8.12 mbgl during post monsoon 2014-23. Specific yield in the zone of water table fluctuation has been taken as 12% and rainfall infiltration factor as 20% (as per norms). As per information available, there is no pumpage / ground water draft from shallow aquifers. Irrigation is being done by deep government tube wells only.

5.2 Method Adopted for Computing Rain Fall Recharge During Monsoon Season

The administrative block has been taken as assessment unit and for computing the block-wise rainfall recharge during monsoon season. Rainfall Infiltration Factor (RIF) Method has been mostly applied as the difference of computing this with Water Level Fluctuations (WLF) Method is more than 20%.

5.3 Ground Water Resource Assessment

The abstract of Dynamic Ground Water Assessment is as follows: -

DYNAMIC GROUND WATER RESOURCE IN SHALLOW AQUIFER

- Recharge from rainfall during monsoon = 1158.09 ham
- Recharge from rainfall during non- monsoon = 313.0 ham
- Recharge from other source during monsoon = 1368.58 ham
- Recharge from other source during non-monsoon = 2674.23 ham
- Total annual ground water recharge = 5513.90 ham
- Total Natural discharge = 551.39 ham
- Annual Extractable Ground Water Resource (Ham) = 4962.51 ham
- Ground water draft as on 31.03.2024 = 3281.70 ham
- Annual GW Allocation for Domestic Use as on 2025 (Ham) = 2513.54 ham
- Net annual ground water availability for future use = 1680.81 ham
- Stage of Ground Water development = 66.13%
- Categorization for future ground water development = Safe

Since, there is no draft from shallow aquifers; however, the ground water is being abstracted from deeper aquifer to the tune of 3281.70 ham/year which places Chandigarh UT under **SAFE** category.

GROUND WATER RECHARGE (GWRE 2024):

There are 11 nos. of Water Bodies / ponds and 534 nos. of RWH & AR structures exist in Chandigarh UT. The details of recharge quantity are given below:

S. N	DATA		QUANTITY (Ham/year)
1	Recharge from rainfall		1471
2	Recharge through Surface Water Irrigation	Recharge through Supply Leakages	2213
		Recharge through STP supply	1529
3	Ground Water Irrigation		119
4	Recharge through tanks & Ponds		110
5	Water Conservation Structures (RTRWH)		71
TOTAL RECHARGE			**5513 ham/year**

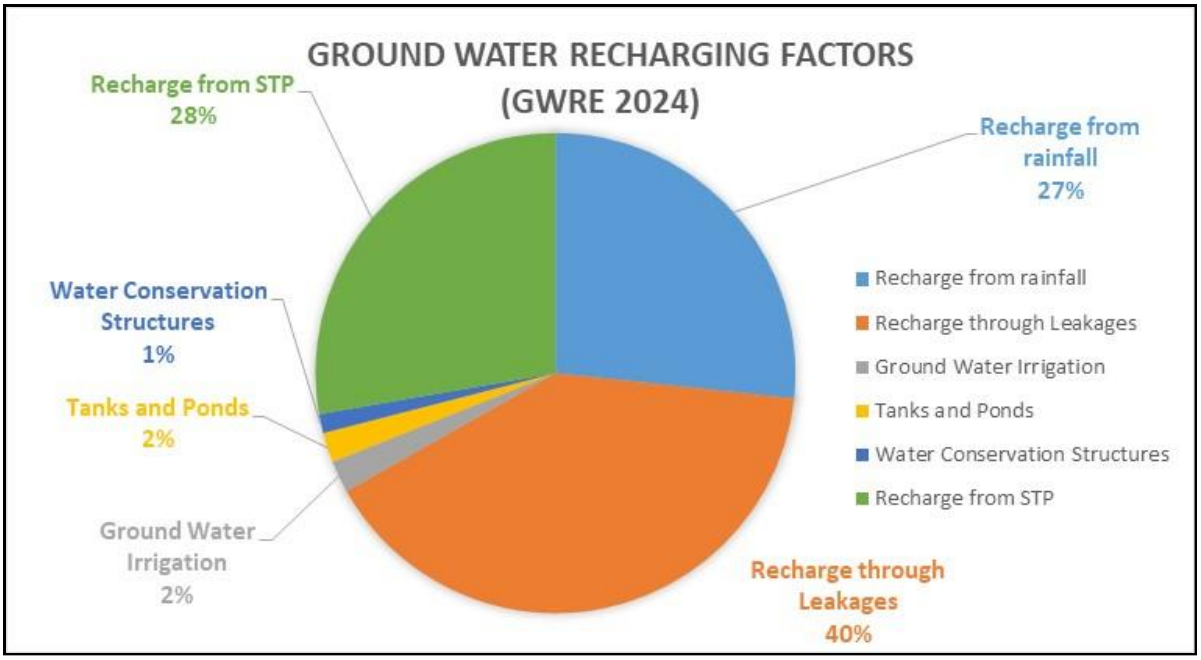


Figure 14: Ground Water Recharging Factors (GWRE 2024)

GROUND WATER DRAFT / EXTRACTION (GWRE 2024):

1. **Domestic Draft:** There are 248 tube wells for drinking / domestic water supply to the rural and urban population. These tube wells tap confined aquifers below 90 m from ground level. The depth of these wells ranges from 200-300 m.
2. **Industrial Draft:** There are 32 nos. of commercial tube wells for industrial water supply and out of which total 23 tube wells are actual in use. These tube wells tap confined aquifers below 90 m from ground level. The depth of these wells ranges from 200-300 m.
3. **Agriculture Draft:** Total 30 nos. of irrigation tube wells in Chandigarh UT are actual in use. These tube wells tap confined aquifers below 90 m from ground level. The depth of these wells ranges from 200-300 m.

S. N	Ground Water Draft (Extraction)	GWRE 2024 QUANTITY (Ham/Year)
1.	Domestic Draft	2513.54
2.	Industrial Draft	217.66
3.	Irrigation Draft	550.50
4.	Total Ground Water Draft	3281.70

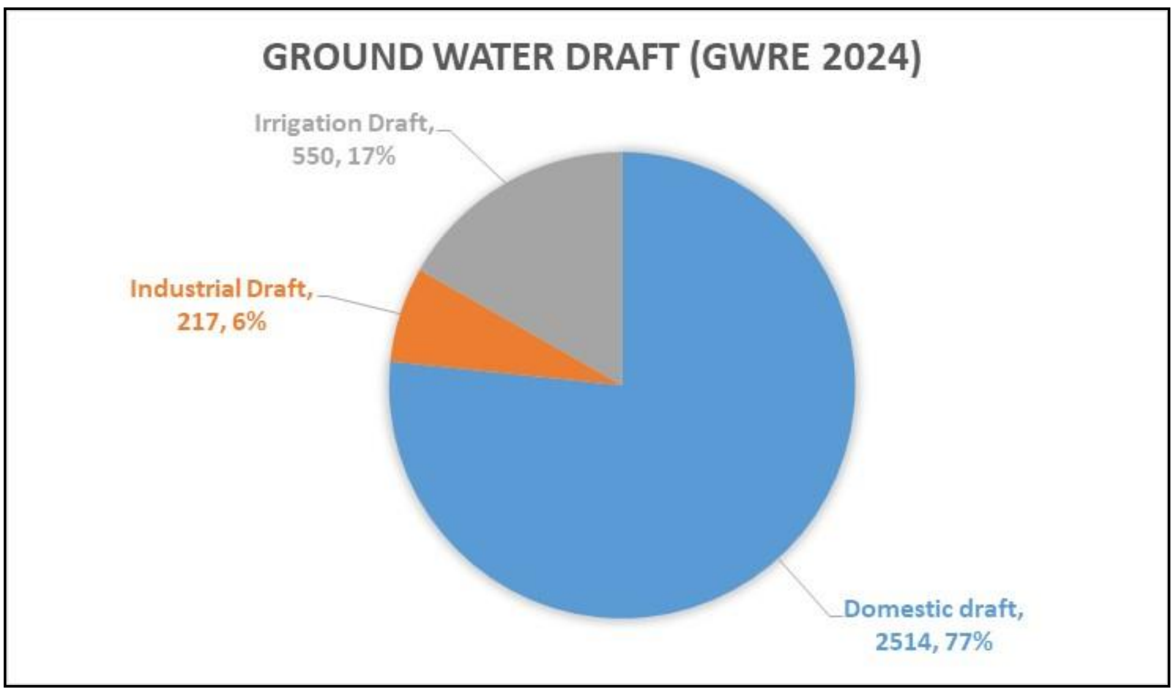


Figure 15: Ground Water Draft (GWRE 2024)

5.4 Ground Water Assessment Comparison of Various Years

COMPARISON OF GROUNDWATER STATUS OF CHANDIGARH UT (SINCE 2004):

	YEAR OF GROUND WATER RESOURCE ESTIMATION								
	2004	**2009**	**2011**	**2013**	**2017**	**2020**	**2022**	**2023**	**2024**
Annual Extractable Ground Water Resource (Ham)	2030	1942	1940	1943	3794	5738.04	4684.21	4841.52	4962.51
Gross Ground Water Draft (Ham)	No data	No data	No data	No data	3378	4624.70	3793.76	3650.81	3281.70
Net GW Availability for Future Irrigation Development (ham)	2030	1942	1940	1943	416	1113.34	890.72	1190.71	1680.81
Over Draft	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Stage of Ground water development in %	-	-	-	-	89%	81%	81%	75%	66%
Category	**SAFE**	**SAFE**	**SAFE**	**SAFE**	**SEMI CRITICAL**	**SEMI CRITICAL**	**SEMI CRITICAL**	**SEMI CRITICAL**	**SAFE**

5.5 Comparison in Dynamic Ground Water Resource in Shallow Aquifers of Chandigarh (UT) - 2023 V/S 2024

5.5.1 Ground Water Recharge:

S. N	RECHARGE	RECHARGE QUANTITY AS ON GWRE 2023 (Ham/Year)	RECHARGE QUANTITY AS ON GWRE 2024 (Ham/Year)	REMARKS
1	**Recharge from rainfall**	1278	1471	Recharge increased due to increase in rainfall.
2	**Recharge through Leakages (Urban water supply leakages)**	2212	2213	Slight increase
3	**Recharge through STP**	1529	1529	No Change
4	**Ground Water Irrigation**	179	119	Irrigation draft reduced therefore recharge decreased (No. of wells are same but pumping hours reduced)
5	**Tanks and Ponds**	110	110	No Change
6	**Water Conservation Structures**	71	71	No Change
TOTAL RECHARGE		**5379**	**5513**	**INCREASED**

5.5.2 Ground Water Extraction / Draft:

S. N	ITEM	GWRE 2023 QUANTITY (Ham/Year)	GWRE 2024 QUANTITY (Ham/Year)	Remarks
1.	Annual Extractable Ground Water Resource / Net Annual Ground Water Availability	4841	4962.51	Increased due to rainfall recharge
2.	Existing GW Draft for Domestic Use	2606.95	2513.54	The draft has been reduced as 22 tube wells have been phased out or deactivated.
3.	Existing GW Draft for Industrial Use	217	217	No Change
4.	Existing GW Draft for Irrigation Use	826.20	550.50	Draft reduced as pumping hours reduced.
5.	Existing GW Draft for All Uses	3650	3281	Reduced
6.	Average Stage of GW Extraction of State	75.40 %	66.13%	Improved
7.	Category	Semi Critical	Safe	Improved

5.6 Long Term Hydrograph trend of Ground Water Monitoring Stations

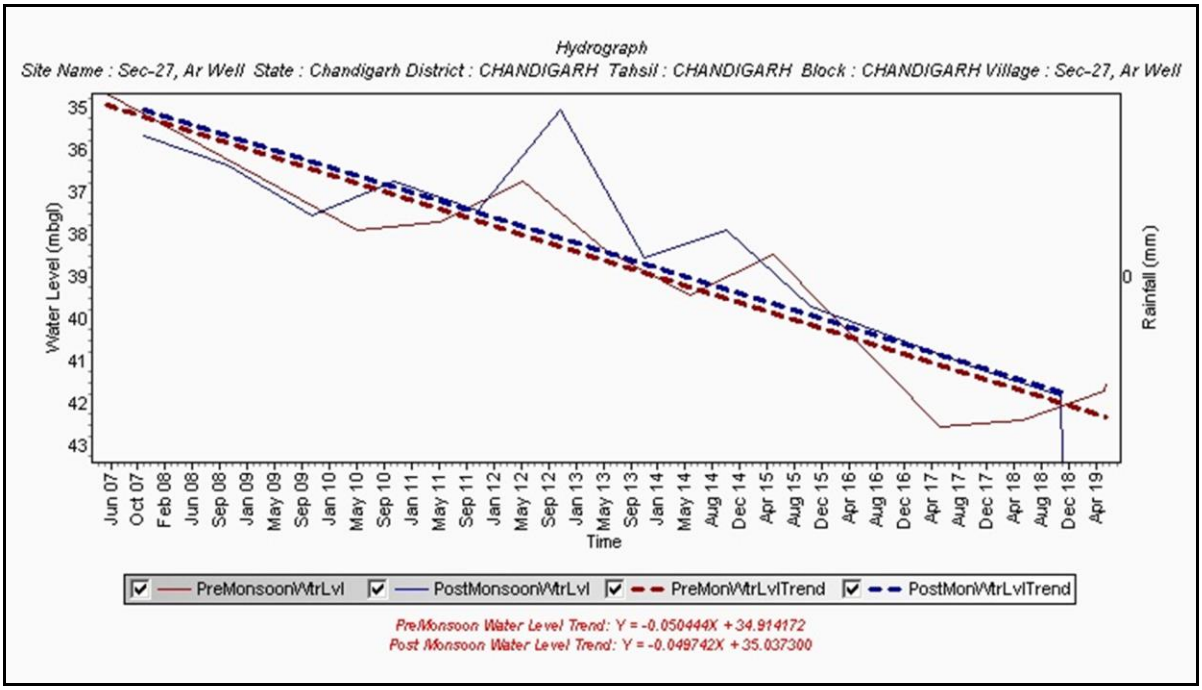


Figure 16: Site name: AR well (Pz), Bhujal Bhawan, Sector 27, Chandigarh

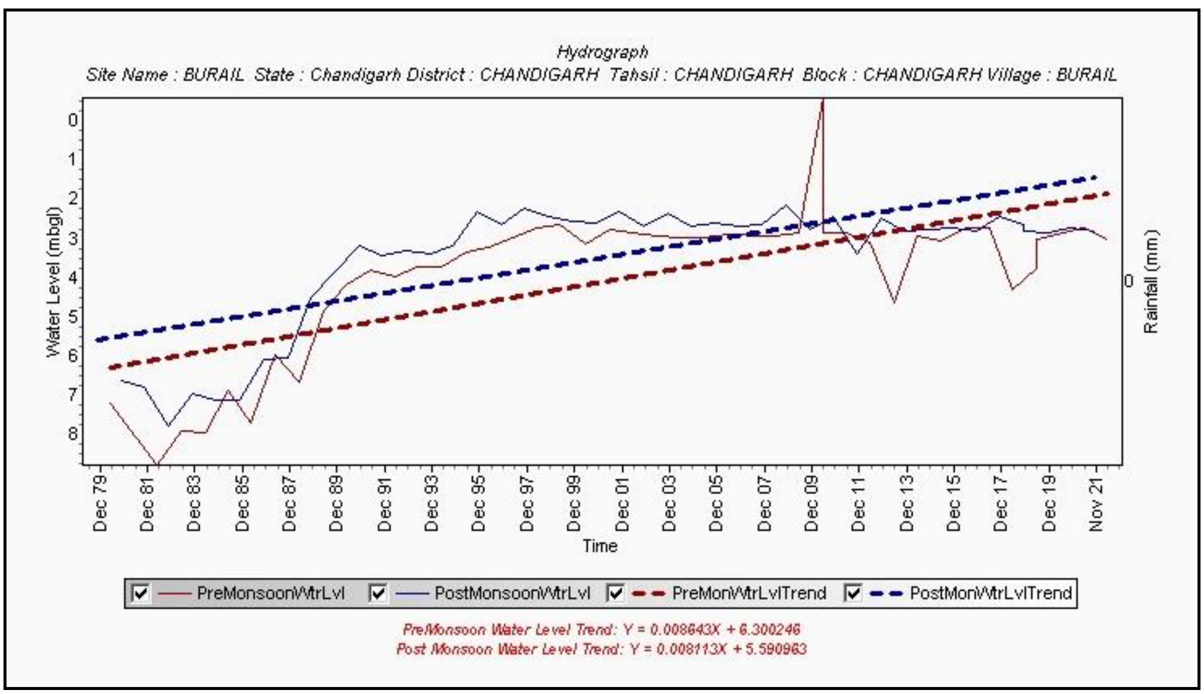


Figure 17: Site name: Dug well, Burail, Chandigarh

5.6 Summary of the Report:

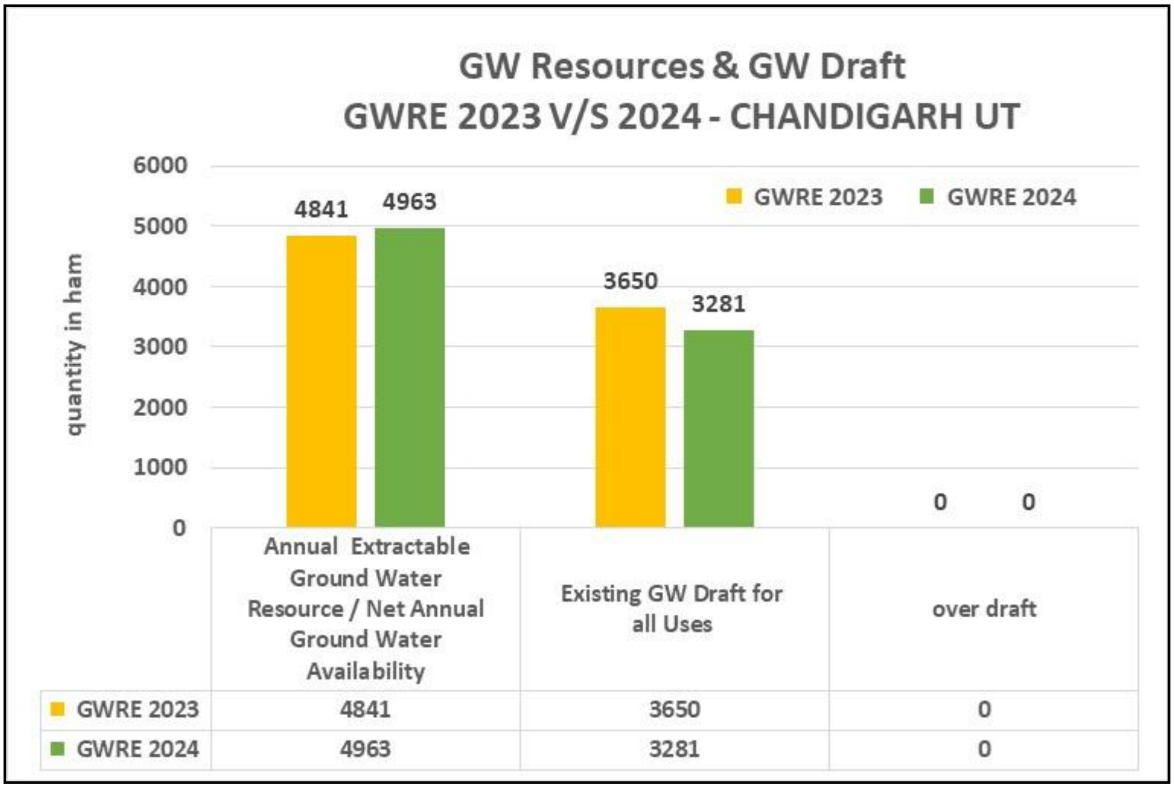


Figure 18: Ground Water Resources & Draft (2023 v/s 2024)

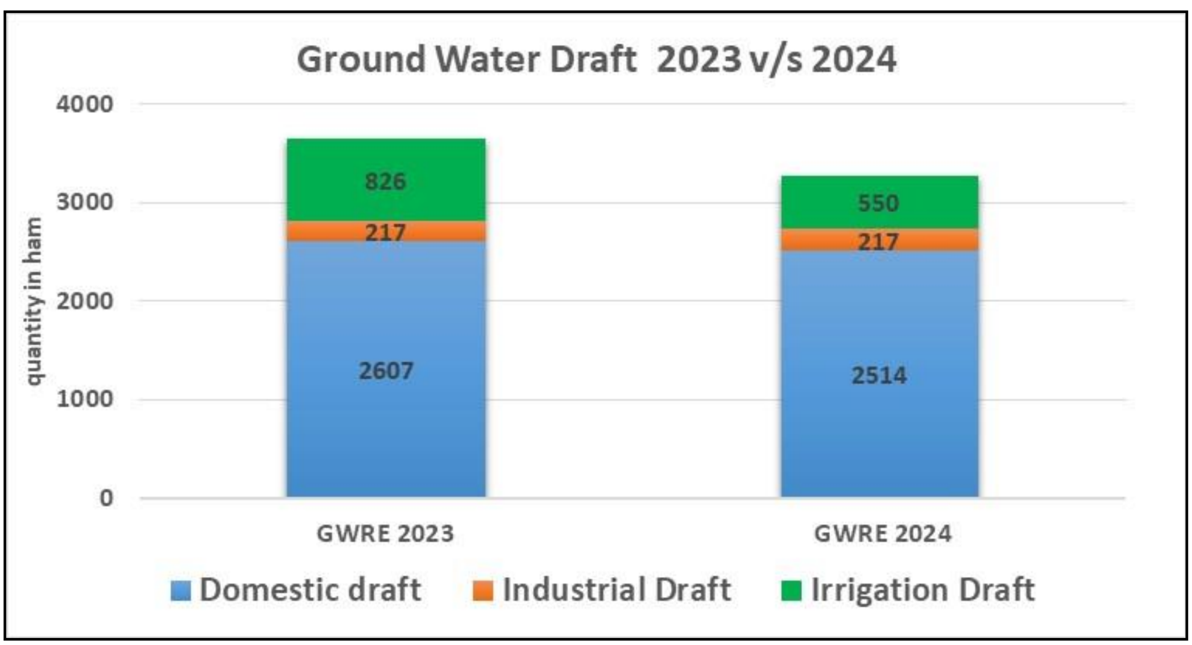


Figure 19: Category wise Ground Water Draft (2023 v/s 2024)

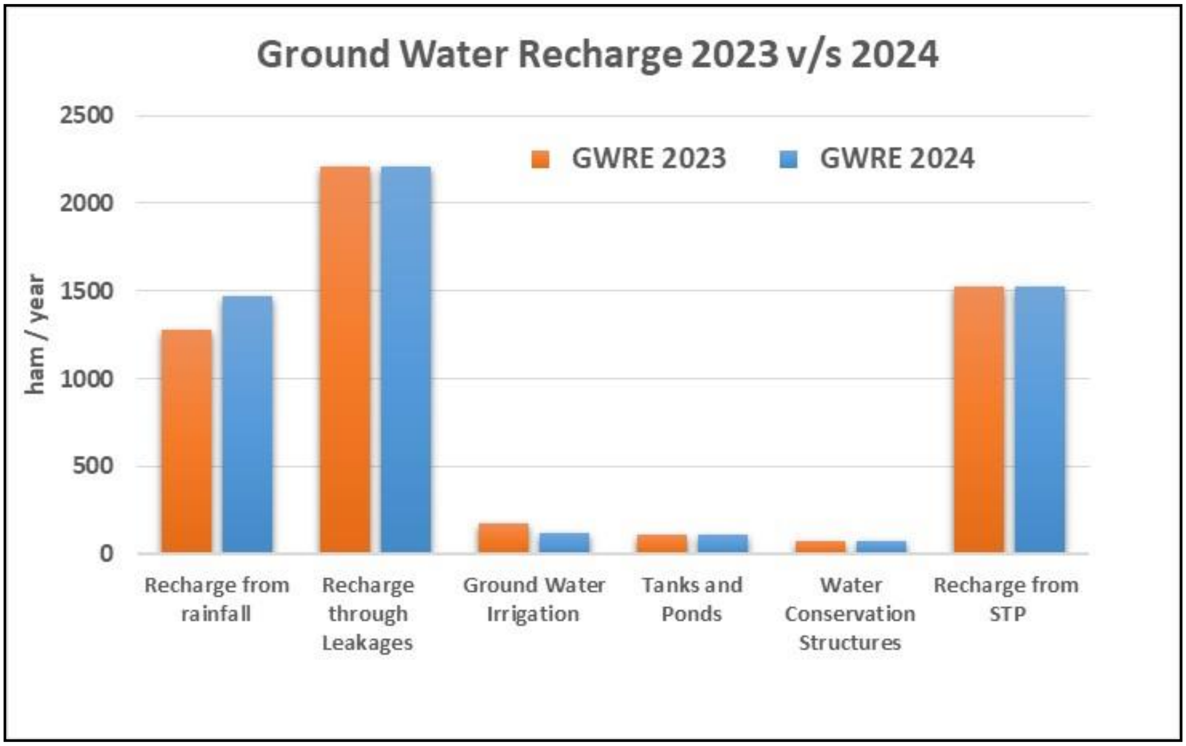


Figure 20: Ground Water Recharge (2023 v/s 2024)

Annexure I: Notification regarding Permanent SLC

Chandigarh Administration
Local Government Department
Notification

Dated, 24 January, 2024

No. 16501-FII(9)-2024/ 1432 In pursuance of the guidelines vide No. 4(139)-CHD/NWR/S&1/2023/-2076 dated 28.04.2023 of Govt of India, Central Ground Water, North Western Region, Central Ground Water Board, the Administrator, Union Territory, Chandigarh is pleased to constitute the permanent **State Level Commtitee (SLC)** in Union Territory, Chandigarh, for coordinating the activities of Ground Water Resource Assessment in UT Chandigarh. The Committee will function as State Level Nodal Agency (SLNA) and as State Level Ground Water Co-ordination Committee (SGWCC) and District Level Ground Water Co-ordination Committee (DGWCC) for all water augmentation/conservation efforts, in the U.T. Chandigarh for sustainable usage of resources for domestic, irrigation and industrial water supply.

The permanent State Level Committee is constituted as under:-

1	The Secretary, Local Govt. Chandigarh Administration	Chairperson
2	The Chief Conservator of Forest, U.T., Chandigarh	Member
3	The Commissioner, U.T., Chandigarh	Member
4.	The Deputy Commissioner, U.T., Chandigarh	Member
5.	The Chief Engineer, MC, Chandigarh	Member
6.	The Chief Engineer, U.T., Chandigarh	Member
7.	The Director Industries, U.T., Chandigarh	Member
8.	The General Manager, National Bank For Agriculture And Rural Development, Sector-34, Chandigarh.	Member
9.	The Director, India Meterorological Department.	Member
10.	The Superintending Engineer, U.T., Chandigarh	Member
11.	The Superintending Engineer, MC, Chandigarh	Member
12.	The Regional Director, Central Ground Water Board, Sector-27, Chandigarh.	Member Secretary

Terms of Reference: The Permanent State Level Committee will perform following functions:-

(a) To re-assess annual ground water recharge of the UT in accordance with the endorsed Ground Water Resource Estimation Methodology.

(b) To estimate the status of utilization of the annual extractable for irrigation, domestic & Industries and categorization of assessment unit for Chandigarh UT.

(c) Planning of Ground Water Management at UT Level based on NAQUIM recommendations.

(d) Convergence of Ground Water Management initiative under various sectors.

(e) Coordination with Nodal Agency for implementation of Ground Water management interventions at UT Level.

(f) Co-ordination of all water conservation/augmentation efforts in the UT.

(g) Preparation of DPRs and execution of the construction of structures through State Level Coordination Committee subject to availability of funds from Central/State scheme.

NITIN KUMAR YADAV, IAS,
Secretary Local Govt. & Urban Development
Chandigarh Administration.

Endst.No. 16501- FII(9)-2024/ Dated, the

A copy is forwarded to the Controller, Printing and Stationery, U.T., Chandigarh, for publishing the above notification in the Chandigarh Administration Gazette(Extra-Ordinary). After the publication please supply 20 copies of the same to this Department for official use.

Joint Secretary Local Govt.,
ChandigarhAdministration.

Endst.No.16501-FII(9)-2024/ 1434 Dated, the 24-1-2024

A copy is forwarded to the Regional Director, Central Ground Water Board, North- Western Region, Bhujal Bhawan, Plot 3-B, Sector-27A, Madhya Marg, Chandigarh, w.r.t. its letter No. 4(139)-CHD/NWR/S&1/2023/-2076 dated 28.04.2023 for kind information.

Joint Secretary Local Govt.,
ChandigarhAdministration.

Endst.No.16501-FII(9)-2024/ Dated, the

A copy is forwarded to the following for kind information,

1. PA/Adviser to the Administrator, U.T., Chandigarh.
2. PA/Secretary Local Govt. Chandigarh Administration.

Joint Secretary Local Govt.,
ChandigarhAdministration.

Endst.No.16501-FII(9)-2024/ Dated, the

A copy is forwarded to the Commissioner, Municipal Corporation, Chandigarh w.r.t its Memo No. CE/MC/8118 dated 14.11.2023. It is requested to inform the all concerned for information and necessary action.

Joint Secretary Local Govt.,
ChandigarhAdministration.

Annexure II – Formation of Permanent SLC

Diary No. 1105208 10/8/23

MUNICIPAL CORPORATION,
ENGINEERING WING,
CHANDIGARH.

No./CE/MC/ 5481

Dated: 10/8/23

To

The Secretary
Local Government Department
Chandigarh Administration
Chandigarh

Subject: **Formation of Permanent State Level Committee (SLC) for Ground Water Resource Assessment-2023 & Ground Water Co-ordination of U.T., Chandigarh.**

Reference: 1st meeting of State Level Committee for Ground Water Resource Assessment 2023 held on 30.06.2023 under the chairmanship of your goodself.

It is submitted that 1st meeting of State Level Committee (SLC) for Ground Water Resource Assessment-2023 was held on 30.06.2023 under the chairmanship of your goodself wherein various issues were discussed.

During the said meeting, it was discussed that a committee pertaining to ground water related matter of the U.T. Chandigarh may be constituted and the same will be responsible for the re-assessment of Ground Water Resources of U.T. Chandigarh as per endorsed methodology and will function as Permanent State Level Committee (SLC).

Further, it is submitted that the same committee may also administer the reappraisal of Master Plan and implementation of NAQUIM recommendations as the Chandigarh has small geographic extent.

During the meeting under reference, it was also agreed that in order to coordinate the various schemes and to avoid overlapping of water conservation/water augmentation projects, the same committee may function as State Level Nodal Agency (SLNA) for all water augmentation/ conservation efforts in the U.T. Chandigarh for making the sources sustainable for domestic, irrigation and industrial water supply. The committee may be referred as State Level Committee for Ground Water Resource Assessment & Ground Water Co-ordination & SGWCC

The composition and term of the reference of the Committee are proposed as under:

1	The Principal Secretary, Local Govt., Chandigarh Administration	Chairperson
2	The Chief Conservator of Forest	Member
3	The Commissioner, M.C., Chandigarh	Member
4	The Deputy Commissioner, U.T. Chandigarh	Member
5	The Chief Engineer, M.C., Chandigarh	Member
6	The Chief Engineer, U.T., Chandigarh	Member
7	The Director, IMD	Member
8	The General Manager, NABARD	Member
9	The Director, Industries	Member
10	The Superintending Engineer, U.T. Chandigarh	Member
11	The Superintending Engineer, M.C., Chandigarh	Member
12	The Regional Director, CGWB	Member Secretary

Terms of Reference: The permanent SLC will perform following functions -

Functions as SLC:

a) To re-assess annual ground water recharge of the UT in accordance with the endorsed Ground Water Resources Estimation Methodology.
b) To Estimate the status of utilization of the annual extractable for Irrigation, domestic & industrial and categorization of assessment unit for Chandigarh UT.

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CE MC

c) Planning of Ground Water Management at UT Level based on NAQUIM recommendations

d) Convergence of Ground Water Management initiative under various sectors

e) Coordination with Nodal Agency for implementation of Ground Water Management interventions at UT Level

f) Coordination of all water conservation/augmentation efforts in the UT

g) Preparation of DPRs and execution of the construction of structures through

- State Level Coordination Committee subject to availability of funds from Central/State schemes

Further it is also submitted that in addition to above permanent SLC will also function as State Ground Water Co-ordination Committee (SGWCC) and District Ground Water Co-ordination Committee (DGWCC)

Therefore I have been directed to request for the followings:

1. To constitute Permanent State Level Committee for Ground Water Resource Assessment as proposed above after including the members from IMD and Forest Department and the same may be referred as State Level Committee for Ground Water Resource Assessment & Ground Water Co-ordination

2. After constitution of said committee, the same may also function as State Level Nodal Agency (SLNA) for all water augmentation/conservation efforts in the U.T. Chandigarh for making the sources sustainable for domestic irrigation and industrial water supply

3. The Permanent State Level Committee may also function as State Ground Water Co-ordination Committee (SGWCC) and District Ground Water Co-ordination Committee (DGWCC)

Executive Engineer (W&E)
for Commissioner
M.C. Chandigarh

DA/Nil

Dated 10/8/23

Endst. No CE/MC/5482-84

A copy of above is forwarded to the followings:-

1. PS to CMC for kind information of the Commissioner Municipal Corporation Chandigarh please.
2. PA to CEMC for kind information of the Chief Engineer Municipal Corporation Chandigarh please
3. The Superintending Engineer M.C. Public Health Circle Chandigarh w.r.t. his office U.O. No. 33726 dated 31.07.23 for his information and necessary action please

Executive Engineer (W&E).
for Commissioner.
M.C. Chandigarh

DA/Nil

Annexure III-A

CATEGORIZATION OF BLOCKS/ MANDALS/ TALUKAS IN INDIA (2024)													
S.No	States / Union Territories	Total No. of Assessed Units	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
1	CHANDIGARH	1	1	100	-	-	-	-	-	-	-	-
	Total	1	1	100	-	-	-	-	-	-	-	-
	Grand Total	1	1	100	-	-	-	-	-	-	-	-

Annexure III-B

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024													
S.No	Name of District	Total No. of Assessed Units	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			No	%	No.	%	No.	%	No.	%	No.	%
1	CHANDIGARH	1	1	100.0	-	-	-	-	-	-	-	-
	Total	1	1	100.0	-	-	-	-	-	-	-	-

Annexure III-C

ANNUAL EXTRACTABLE RESOURCE OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES, 2024

CHANDIGARH

S.No	State/Union Territories	Total Annual Extractable Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%
1	**CHANDIGARH**	49.63	49.63	100	-	-	-	-	-	-	-	-
	Total	49.63	49.63	100	-	-	-	-	-	-	-	-
	Grand Total	49.63	49.63	100	-	-	-	-	-	-	-	-

Annexure III-D

AREA OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES IN INDIA (2024)

S.No	States / Union Territories	Total Geographical Area of Assessed Units (in sq. km)	Recharge Worthy Area (in sq. km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
				Recharge Worthy Area in sq. km	%	Recharge Worthy Area in sq. km	%	Recharge Worthy Area in sq. km	%	Recharge Worthy Area in sq. km	%	Recharge Worthy Area in sq.km	%
1	**CHANDIGARH**	114	114	114	100	-	-	-	-	-	-	-	-
	Total	114	114	114	100	-	-	-	-	-	-	-	-
	Grand Total	114	114	114	100	-	-	-	-	-	-	-	-

Annexure III-E

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024													
CHANDIGARH													
S.No	Name of District	Total Recharge Worthy Area of Assessed Units (in sq.km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline		
			Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	
1	**CHANDIGARH**	114.0	114.0	100.0	-	-	-	-	-	-	-	-	
	Total	114.0	114.0	100.0	-	-	-	-	-	-	-	-	

Annexure III-F

State-Wise Summary of Assessment Units Improved Or Deteriorated From 2023 To 2024 Assessment				
S. No	Name of States / Union Territories	Number of Assessment Units Improved	Number of Assessment Units Deteriorated	Number of Assessment Units With No Change
1	**CHANDIGARH**	1	0	0

Annexure IV-A

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024															
CHANDIGARH															
S.NO	State/Union Territories	Ground Water Recharge					Total Natural Discharges	Annual Extractable Ground Water Resource	Current Annual Ground Water Extraction				Annual GW Allocation for Domestic use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
		Monsoon Season		Non-Monsoon Season		Total Annual Ground Water Recharge			Irrigation	Industrial	Domestic	Total			
		Recharge from rainfall	Recharge from other Sources	Recharge from Rainfall	Recharge from other Sources										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	CHANDIGARH	1158.09	1368.58	313	2674.23	5513.9	551.39	4962.51	550.5	217.66	2513.54	3281.7	2513.54	1680.81	66.13
	Total (Ham)	1158.09	1368.58	313	2674.23	5513.9	551.39	4962.51	550.5	217.66	2513.54	3281.7	2513.54	1680.81	66.13
	Total (Bcm)	0.01	0.01	0	0.03	0.06	0.01	0.05	0.01	0	0.03	0.03	0.03	0.02	66.13

Annexure IV-B

SUMMARY OF ASSESSMENT UNIT-WISE CATEGORIZATION (2024), as on 31.03.2024							
CHANDIGARH							
S. No.	Union Territory	Total Area (sq. km)	Over-exploited	Critical	Semi-critical	Safe	Poor Quality
1	2	3	4	5	6	7	8
	Chandigarh	114	-	-	-	114	-

Annexure V-A

State-Wise Summary of Assessment Units Improved Or Deteriorated From 2023 To 2024 Assessment				
S. No	Name of States / Union Territories	Number of Assessment Units Improved	Number of Assessment Units Deteriorated	Number of Assessment Units With No Change
1	**CHANDIGARH**	1	0	0

Annexure V-B

COMPARISON OF CATEGORIZATION OF ASSESSMENT UNITS (2023 AND 2024)									
CHANDIGARH									
S.No	Name of District	Name of Assessment Unit	Stage of Ground Water Extraction (%) 2023	Categorization in2023	Name of District	Name of Assessment Unit	Stage of Ground Water Extraction (%) 2024	Categorization in2024	Remark
1	**CHANDIGARH**	CHANDIGARH	75.40	semi critical	**CHANDIGARH**	CHANDIGARH	66.12	safe	Improved

Annexure V-C

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024															
INDIA															
S. NO	States / Union Territories	Ground Water Recharge					Total Natural Discharges	Annual Extractable Ground Water Resource	Current Annual Ground Water Extraction				Annual GW Allocation for Domestic use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction(%)
		Monsoon Season		Non-Monsoon Season		Total Annual Ground Water Recharge									
		Recharge from rainfall	Recharge from other Sources	Recharge from Rainfall	Recharge from other Sources				Irrigation	Industrial	Domestic	Total			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	CHANDIGARH	0.01	0.01	0	0.03	0.06	0.01	0.05	0.01	0	0.03	0.03	0.03	0.02	66.13
	Total(bcm)	0.01	0.01	0	0.03	0.06	0.01	0.05	0.01	0	0.03	0.03	0.03	0.02	66.13