DYNAMIC GROUND WATER RESOURCES OF NAGALAND, 2024

Central Ground Water Board
Department of Water Resources,
River Development & Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

Nagaland
January, 2025

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Foreword

Water is necessary for life, but its availability and sustainability is not uniform in the State. Groundwater is an integral part of the hydrological cycle and is a valuable natural resource and primary source of water for agriculture, domestic, and industrial uses. The uncontrolled withdrawal of ground water for meeting the increased demands for agriculture, industries and domestic use has resulted in depletion of the groundwater. It is essential that groundwater be used and managed in a sustainable way in order to maintain present and future demands.

The dynamic groundwater resources of Nagaland, 2024 has been assessed following a well defined Groundwater Estimation Methodology, 2015 (GEC-2015) through "India Groundwater Resource Estimation System" (INGRES), software a GIS based web platform. The assessment is carried out jointly by CGWB and State Groundwater related Departments with the Directorate of Geology and Mining, Government of Nagaland as the State Nodal Department. The annual groundwater resource assessment is providing a clear/better understanding of groundwater dynamics, its recharge, extraction and serves as the foundation for planning, execution and implementation of strategies for sustainable management of groundwater resources in the State of Nagaland.

I sincerely appreciate the work done by Central Ground Water Board, Regional Office, Guwahati, in compiling this report and bringing out this publication on the status of ground water resources, availability, quality and utilization in the State. I also extend my appreciation to the officers of CGWB and officers from State Groundwater nodal Department for their tireless efforts in conducting resource assessment of the State and members of the State Level Committee (SLC), Nagaland for their valuable inputs and guidance in timely completion of the assessment and Compilation.

I hope this comprehensive report will serve as a valuable resource to the decision makers, planners and all concerned stakeholders for ensuring sustainability of groundwater resources in the State.

Kohima
January 2025

John Kevi Angami
Commissioner and Secretary, Geology and Mining &
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भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
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Government of India
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Message

Groundwater plays an important role in the Nation's economic growth and forms a vital component of our ecological system. India's agricultural productivity, industrial output, and domestic water supply are heavily reliant on groundwater. However, rising water demands have led to excessive groundwater extraction in many parts of India, exceeding the annual replenishment leading to decline in groundwater level. A thorough assessment of this hidden resources is essential for developing strategies for management and regulatory measures. Since 2022, it has been decided to carry out the estimation of the Dynamic Groundwater Resources of the nation every year to provide the planners, decision makers and all stakeholders with reliable data/information for taking timely measures for sustainable management of groundwater resources.

The assessment of dynamic groundwater resources of **Nagaland, 2024** is based on the Groundwater Estimation Methodology of 2015 (GEC-2015), which comprehensively factors in all relevant parameters contributing to groundwater recharge and extraction. The Dynamic Groundwater Resource Assessment of 2024 (GWRA-2024) of **Nagaland** is a collaborative effort involving both the **State Nodal Department of Ground Water** and the Central Ground Water Board, North Eastern Region by utilizing the INDIA-Ground Water Resource Estimation System (IN-GRES) Software.

I extend my heartfelt appreciation to the dedicated officers of CGWB, NER for their significant role in compiling the state-level data. My gratitude also goes to the officers of CGWB and State Ground Water Nodal Departments of **Nagaland** for their relentless efforts in conducting assessments according to the planned schedule.

The valuable contributions of the SLC members in refining the State Report of **Nagaland** are also acknowledged. I hope this State level compilation will serve as an important document for planners, decisionmakers, and all concerned stakeholders in prioritizing actions necessary to ensure the sustainability of groundwater resources in the state.

Faridabad
January, 2025

(**T. S. Anitha Shyam**)
Member (South)

Sri N Varadaraj
Member (East)

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
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Groundwater is considered the "backbone" of India's water security, fulfilling nearly 80% of the country's drinking water needs and providing around two-thirds of the water required for irrigation, making it a critical resource for both rural and urban populations. India's agricultural productivity, industrial output, and domestic water supply are heavily reliant on groundwater. Rapid rise in population increases demand for water. Rise in urban population increases load on management of waste and polluted water. India is the largest user of groundwater accounting for approximately 25% of the total global withdrawal. Indian cities cater to about 48% of their water supply from groundwater. With rise in population, groundwater use is expected to rise further.

A systematic assessment of this hidden resources is essential for developing strategies for management and regulatory measures. Since 2022, it has been decided to carry out the estimation of the Dynamic Groundwater Resources of Nagaland every year to provide the planners, decision makers and all stakeholders with reliable data/information for taking timely measures for sustainable management of groundwater resources.

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The valuable contributions of the CLEG and SLC members in refining the Report are also acknowledged. I hope this state report on Ground Water Resource,2024 will serve as an important document for planners, decision makers, and all concerned stakeholders in prioritizing actions necessary to ensure the sustainability of groundwater resources in the country.

Faridabad
January, 2025

(N Varadaraj)
Member (East)

तपन चक्रवर्ती
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Tapan Chakraborty
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पूर्वोत्तर क्षेत्र
जल शक्ति मंत्रालय
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Government of India
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North Eastern Region
Ministry of Jal Shakti
Department of WR, RD & GR

PREFACE

The State of Nagaland, situated in the Northeast of India, comprises of hilly terrain bordered in parts of the west by low lying, alluvial tracts adjoining the State of Assam.The State is located in the northern extension of the Arakan Yoma ranges representing orogenic upheavals in this part of the country during Cretaceous and Tertiary periods. The state is largely a hilly region and the highest mountain in the state is Saramati which is 3841 m above mean sea level. The hills are steep and are separated by rivers which flow either to the east or west creating deep gorges between the hill ranges. In spite of good rainfall in the state, the major part of rainfall is lost as surface run-off except Dimapur valley. Hence, there is acute shortage of water during the pre-monsoon. The prominent sources of water are streams, small rivers, springs and nallas which also act as main contributors to the ground water storage. There is necessity to assess the ground water resource potentialof the state periodically for scientific planning of its development. Keeping this objective in view, the ground water resource potential of Nagaland has been reassessed based on 'Ground Water Resource Estimation Methodology – 2015' (GEC'15).

This report presents the Dynamic Ground Water Resources of Nagaland estimated based on GEC'2015 in web based IN-GRESS software. The present assessment has been done for 52 blocks of eleven districts. The annual extractable groundwater resources is 0.56 BCM, of which annual allocation for domestic needs up to 2025 is 0.02 BCM and 0.53 BCM is available for irrigation and other uses. Present stage of ground water extraction in the state is only 4.72%.

The estimation of dynamic groundwater resources for Nagaland was jointly done by the Directorate of Geology and Mining, Govt. of Nagaland and Central Ground WaterBoard, North Eastern Region. The efforts made by the scientists of Central Ground Water Board, North Eastern Region, Guwahati, and State Unit Office, Shillong and Directorate of Geology and Mining; Govt of Nagaland are commendable.

I firmly believe that the report will throw light on the Future Ground Water Availability for various uses including irrigation and domestic sectors and serve as a crucial resource for policymakers, technical experts, professionals, and user agencies, enabling them to manage groundwater development in a planned and sustainable manner for the state of Nagaland.

Guwahati
January 2025

(Tapan Chakraborty)
Regional Director
CGWB, NER, Guwahati

CONTENTS

DYNAMIC GROUND WATER RESOURCES OF NAGALAND, 2024

AT A GLANCE

1.	Total Annual Ground Water Recharge	: 0.62 BCM
2.	Annual Extractable Ground Water Resources	: 0.56 BCM
3.	Annual Ground Water Extraction	: 0.03 BCM
4.	Stage of Ground Water Extraction	: 4.72 %

CATEGORIZATION OF ASSESSMENT UNITS

(Blocks/ Mandals/ Taluks)

Sl.No	Category	Number of Assessment Units		Recharge worthy Area		Annual Extractable Ground Water Resource	
		Number	%	in lakh sq. km	%	(in bcm)	%
1	Safe	52	100	0.039	100	0.56	100
2	Semi Critical	-	-	-	-	-	-
3	Critical	-	-	-	-	-	-
4	Over-Exploited	-	-	-	-	-	-
5	Saline	-	-	-	-	-	-
	TOTAL	52	100	0.039	100	0.56	100

EXECUTIVE SUMMARY

The State of Nagaland is one of the seven states in North Eastern Region which lies between Latitudes 25°06′ N and 27°04′ N and Longitudes; 93°20′ E and 95°15′ E. It is bounded by International boundary of Myanmar in the East, and the North, West and South of the state is bounded by the States of Arunachal Pradesh, Assam and Manipur respectively, covering an area of 16,579 sq.km. Kohima is the state capital. The state is basically a hilly terrain with intermontane valleys.

Forest covers about 52% of the total geographic area. Traditional "Jhum" or shifting cultivation is widely practiced by the people of Nagaland. Terrace Rice cultivation is also practiced to a considerable extend.

The state is predominantly occupied by high to moderate hill ranges. Geomorphologically, the state can be divided into eight geomorphic units. Drainage of the state is mainly structurally controlled.

Hydrogeological condition of the state is mainly controlled by semi-consolidated and unconsolidated formations. The moderate to high hill ranges, comprising semi-consolidated rock formations belonging to Lower Tertiary formation occupying the south-central part of the state form basically a run-off zone. The Upper Tertiary group of rocks, in the northern part of the state, forms low to moderate altitude hill ranges with structural valleys. This zone is also basically a run-off zone with moderate to low infiltration.

Valleys constitute around 22 % of the geographical area and are spread in northern and south western part of the state. The structural valleys comprise unconsolidated sediments with variable thickness which show moderate to high infiltration, less run-off and recharge condition. These valleys comprised of clay, silt, sand, gravel, kankar, pebble, cobble/ boulder etc are suitable for ground water development through construction well.

The state receives heavy rainfall under the influence of SW monsoon and occasionally in winter. Copious rainfall is received in certain parts of the states. However, rainfall varies from place to place and altitude to altitude.

In the current assessment year, both pre and post monsoon depth to water level in the state was found within 15 mbgl. No significant decline in ground water level trend had been observed. Chemical Quality of groundwater is generally good and suitable for domestic, irrigation and industrial uses. However, presence of high iron content is found in pockets.

Assessment of Dynamic GW resources of the state has been done for 52 assessment units. The assessment has been carried out block-wise. The recharge worthy area of the state is only 3855.07 sq.km.

The total annual ground water recharge in the state has been assessed as 0.62 BCM. The Annual Extractable Ground Water Resources of the state is 0.56 BCM after deducting the natural discharge. Present Ground Water Extraction is 0.03 BCM out of which 0.01 BCM extraction is on account of irrigation, 0 BCM is on account of Industrial extraction and the annual domestic extraction is 0.02 BCM. The annual allocation for Domestic use has been made as 0.02 BCM based upon the population data projected upto year 2025. The over-all stage of ground water extraction of the state is 4.72%.

CHAPTER 1

INTRODUCTION

The state of Nagaland comprising eleven districts as per 2011 census, covers an area of 16579 sq. km. The state is basically a hilly terrain with rolling hill ranges, tablelands and narrow ravines. As per 2011 Census, the total population of the State is 1978502 out of which male population is 10,24,649 and female population is 9,53,853. The density of population varies from 58 (Peren) to 409 (Dimapur) persons per sq.km. The rural population constitutes 71% of the total population. Decadal growth rate between 2001 & 2011 is – 0.58%. Agriculture is the main livelihood of the people of the state and 80% (approx.) of the total population depend upon agriculture.

Geological formation occurring in the state ranges in age from Pre-Cretaceous to Recent to Sub-Recent. Geotectonically, four distinct domains have been identified in the Naga hills, which are framed between the foreland spur of Shillong and Mikir Massifs to the west and central Myanmar basin to the east. These are (1) Assam Shelf, (2) Schuppen Belt, outer belt of imbricate, anastomising thrusts (Evans and Mathur 1964), (3) Inner Palaeogene Fold Belt, comprising thick folded sequence of Disang and Barail rocks, and (4) Ophiolitic Complex occurring further east, close to Indo-Myanmar border, associated with Late Mesozoic-Tertiary sediments.

The state is predominantly occupied by high to moderate hill ranges. Geomorphologically, the state can be divided into eight geomorphic units. Drainage of the state is mainly structurally controlled. Some of the prominent rivers are Tizit, Tiru, Lakong, Dikhu, Dayan, Longlang, Tuilen, Tuphoja etc.

Hydrogeological condition of the state is mainly controlled by semi-consolidated and unconsolidated formations. The moderate to high hill ranges, comprising semi-consolidated rock formations belonging to Lower Tertiary formation occupying the south-central part of the state form basically a run-off zone. The Upper Tertiary group of rocks, in the northern part of the state, forms low to moderate altitude hill ranges with structural valleys. This zone is also basically a run-off zone with moderate to low infiltration.

In the hilly area ground water manifests as springs at different contour levels. Springs play a major role in managing the water resources of Nagaland. Both ephemeral and perennial types of springs are present in the state. Ephemeral types are present mainly in higher elevation. The springs also act as main contributors to the ground water storage.

Valleys constitute around 22 % of the geographical area and are spread in northern and south western part of the state. Except, Dimapur valley others are yet to achieve momentum for ground water development. The structural valleys comprise unconsolidated sediments with variable thickness which show moderate to high infiltration, less run-off and recharge condition. These valleys comprised of clay, silt, sand, gravel, kankar, pebble, cobble/ boulder etc are suitable for ground water development through construction well.

The entire state has been categorised as "Safe" from ground water extraction point of view. The Annual Ground Water Recharge is 61717.4 Ham and Net Annual Ground Water Availability for future use is 53489.6 Ham. The Annual extractable Ground Water resource is 56217.94 Ham and the Stage of Ground Water Extraction is 4.72 % only.

The state of Nagaland enjoys sub-tropical to sub-montane temperate climate. The climate of the state varies to a great extent, even in places within a short distance. This variation in climate is mainly due to its physiography There are basically four seasons, viz. Pre-monsoon, Monsoon or Rainy season, Autumn and Winter. The pre-monsoon season commences from March to May, characterized by rainfall, thunder storm and relatively high temperatures. During this period, the temperature varies from 12^{o}C to 34^{o}C. The rainy season commences with the onset of southwest monsoon during June and lasts up to September. This encourages a lot of wet cultivation in the state. Then, it is followed by short autumn from mid-October to November, which also indicates the slow retreating of monsoon with clear and sunny sky. The winter season commences from December to the end of February. This is the coldest season of the year with sharp decline in the temperature. During this period the state experiences very cold nights with temperature varying from 4° to 28°C. Winter months are basically dry with reducing diurnal range of temperature.

Ground water in the state is slightly alkaline to neutral in nature. Electrical conductivity, total dissolved solids are very less, indicating soft water. Other constituents are within permissible limit of drinking, agricultural and industrial water standard set by BIS. In general, the chemical quality of ground water is good and potable in the state. Chemical analysis of ground water showed that there is ground water pollution by presence of excess nitrate in some places.

The previous assessment of dynamic groundwater resources of Nagaland was carried out block-wise during 2022-23. The assessment was done for 52 blocks of the state. The current (2023-24) dynamic ground water resources of the state has been assessed jointly by Central Ground Water Board and Directorate of Geology and Mining, Govt. of Nagaland based on GEC 2015 methodology. The assessment has been done block-wise. Watershed as an assessment unit could not be taken up due to paucity of watershed wise data in the state.

For the current assessment, various data provided by Water Resources Department, Soil and Water Conservation Department, Agriculture Department, Govt. of Nagaland have been used. For population data, projected population based on 2011 census report has been used.

Ground water regime:

In Nagaland, ground water in general, occurs under unconfined to semi-confined conditions. Hydrogeological condition of the state is mainly controlled by two distinct formations, i.e., semi-consolidated and unconsolidated formations. The semi-consolidated formations gradually experience more rigidness from north to south and the unconsolidated formations attaining maturity from south to north. The structural valleys comprise unconsolidated sediments, with variable thickness, show moderate to high infiltration, less run-off and recharge condition. Intermontane valleys are suitable for ground water development through construction of dug wells and tube wells.

Movement and occurrence of ground water in consolidated formation is controlled by secondary porosity like joints, faults etc. Yield is expected to be moderate to good along the fractures where intersection of more than one set of fractures and joints are present.

In unconsolidated formation, the pre and post monsoon water levels generally varies from 2.21 to 13.56 mbgl and 2.25 to 11.51 mbgl respectively..

Water level trends for the period of last 10 years shows that most of the fall and rise have been recorded within 4 m.

Spring:

Spring is defined as a localized natural discharge of ground water appearing at the ground surface as a current of flowing water through well-defined outlets. Though ground water prospect is low in hilly areas, ground water emanates as springs. Nagaland endowed with abundant rainfall, numerous springs appears in the state during rainy season. However, most of the spring dries up or its discharge dwindles during the lean period. Traditionally tribal people living in the hilly areas use spring water for drinking and domestic purpose. In the foothill areas people used to arrest the spring water by constructing seasonal / permanent bund on small streamlets / cherras and use for irrigation purpose and also used for drinking & domestic purposes. In the hill slopes people divert spring water for irrigation purposes The springs are mainly located in the foothills and intermontane valleys. Some perennial springs flow throughout the year but their yield decrease significantly during the dry season (March – April). However, several perennial springs potential with good potential exist in the state. Most of the springs show drastic increase in discharge during post-monsoon season suggesting the direct influence of rainfall recharge.

Springs found in Nagaland are mainly depression (topographic) and fractured types. It has also been observed that the discharge of springs increases during monsoon season and gradually decreases with the cessation in rainfall.

Ground Water Quality

Quality of water is one of the important factors for its usefulness. The water quality requirement varies depending on its utility. The quality of water is governed by the presence of suspended particle and dissolved gases/solutes. Ground water contains various salts in dissolved form, which determines its utility. While passing through the porous media made up of different types of rock formations, the ground water dissolves various salts depending upon the parent rock material. However, ground water is usually free from bacteriological contamination.

The suitability of water for various purposes such as drinking, industrial uses, agriculture uses etc. is dependent on the presence of various chemical constituents. The standard norm for different purposes has been set by different organizations like Bureau of Indian Standard (BIS), World Health Organization (WHO), Indian Council of Medical Research (ICMR) etc. The prescribed guideline values are not mandatory limits and are based on socio-economic and environment conditions of a nation. CGWB follows the standard set by BIS (2003) for recommendations of drinking water standards. In general, the water of the state is slightly alkaline to neutral in nature. Electrical conductivity, total dissolved solids are very less, indicating soft water. Other constituents are within permissible limit of drinking, agricultural and industrial water standard set by BIS. So far no chemical pollution has been detected in the state. However, the shallow water bearing zone in the valleys of northernmost part of the state, the iron content in ground water is higher than the permissible limit. Spring water is the main source of drinking water in the hilly areas of the state, which is safe from chemical contamination point of view. However, the bacteriological contamination should be checked before spring water is used for drinking purpose.

CHAPTER 2

GROUND WATER RESOURCE ESTIMATION METHODOLOGY

Ground water resource as in 2024 have been estimated following the guidelines mentioned in the GEC 2015 methodology using appropriate assumptions depending on data availability. The principal attributes of GEC 2015 methodology are given below:

It is also important to add that as it is advisable to restrict the groundwater development as far as possible to annual replenishable resources, the categorization also considers the relation between the annual replenishment and groundwater development. An area devoid of ground water potential may not be considered for development and may remain safe whereas an area with good groundwater potential may be developed and may become over exploited over a period. Thus, water augmentation efforts can be successful in such areas, where the groundwater potential is high and there is scope for augmentation.

2.1. GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER

Though the assessment of ground water resources includes assessment of dynamic and in-storage resources, the development planning should mainly focus on dynamic resource as it gets replenished on an annual basis. Changes in static or in-storage resources normally reflect long-term impacts of ground water mining. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper planning for augmentation in the succeeding excess rainfall years.

2.1.1. Assessment of Annually Replenishable or Dynamic Ground Water Resources

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

$$\boldsymbol{Inflow - Outflow = Change\ in\ Storage(of\ an\ aquifer)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (\mathbf{1})$$

Equation (1) can be further elaborated as –

$$\boldsymbol{\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B} \dots\dots.. (\mathbf{2})$$

Where,

ΔS - Change is 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 & 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

Due to lack of data for all the components in most of the assessment units, at present the water budget has been assessed based on major components only, taking into consideration certain reasonable assumptions. The estimation has been 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.

2.1.1.1. Rainfall Recharge

Ground water recharge has been estimated on ground water level fluctuation and specific yield approach since this method considers the response of ground water levels to ground water input and output components. In units or subareas where adequate data on ground water level fluctuations are not available, ground water recharge is estimated using rainfall infiltration factor method only. The rainfall recharge during non-monsoon season has been estimated using rainfall infiltration factor method only.

2.1.1.1.1.Ground Water Level Fluctuation Method

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

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

Where,

ΔS - Change is storage
R_{RF} - Rainfall recharge
R_{STR} - Recharge from stream channels
R_{SWI} - Recharge from surface water irrigation
R_{GWI} - Recharge from ground water irrigation
R_{TP} - Recharge from Tanks& 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 have another term i.e., Recharge due to canals (R_C) and the equation is as follows:

$$\Delta S = R_{RF} + R_{STR} + R_C + R_{SWI} + R_{GWI} + R_{TP} + R_{WCS} \pm VF \pm LF - GE - T - E - B \ldots\ldots\ldots\ldots...(4)$$

The change in storage has been estimated using the following equation:

$$\Delta S = \Delta h \times A \times S_Y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

ΔS - Change is storage

Δh - rise in water level in the monsoon season

A - Area for computation of recharge

S_Y - Specific Yield

Substituting the expression in equation (5) for storage increase ΔS in terms of water level fluctuation and specific yield, the equations (3) & (4) becomes (6) & (7) for non-command and command sub-units,

$$R_{RF} = \Delta h \times A \times S_Y - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \ldots\ldots\ldots (6)$$

$$R_{RF} = \Delta h \times A \times S_Y - R_{STR} - R_C - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B \ldots\ldots (7)$$

Where base flow/ recharge to/from streams have not been estimated, the same is assumed to be zero. The rainfall recharge obtained by using equation (6) and (7) provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate has been normalized for the normal monsoon season rainfall as per the procedure indicated below.

Normalization of Rainfall Recharge

Let R_i be the rainfall recharge and r_i be the associated rainfall. The subscript "i" takes values 1 to N where N is the number of years for which data is available. This should be at least 5. The rainfall recharge, R_i is obtained as per equation (6) & equation (7) depending on the sub-unit for which the normalization is being done.

After the pairs of data on R_i and r_i have been obtained as described above, a normalisation procedure is carried out for obtaining the rainfall recharge corresponding to the normal monsoon season rainfall. Let r(normal) be the normal monsoon season rainfall obtained as the average of recent 30 to 50 years of monsoon season rainfall. Two methods are possible for the normalisation procedure. The first method is based on a linear relationship between recharge and rainfall of the form

$$R = ar \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

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

$$R_{RF}(normal) = \frac{\sum_{i=1}^{N}\left[R_i \frac{r(normal)}{r_i}\right]}{N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

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- Rainfall in the monsoon season for the i^{th} year
N - No. of years for which 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,

$$R_{RF}(normal) = a \times r(normal) + b \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (10)$$

Where,

$R_{RF}(normal)$ - Normalized Rainfall Recharge in the monsoon season
r(normal) - Normal 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 has been followed in the second method is as given below:

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (11)$$

$$b = \frac{S_2 - aS_1}{N} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (12)$$

Where,

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

2.1.1.1.2.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, the rainfall recharge obtained from water level fluctuation approach has been compared with that estimated using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship –

$$R_{RF} = RFIF \times A \times \frac{(R - a)}{1000} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (13)$$

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 threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is considered while estimating ground water recharge using rainfall infiltration factor method. The minimum threshold limit is in accordance with the relation shown in equation (13) and the maximum threshold limit is based on the premise that after a certain limit, the rate of storm rain is too high to contribute to infiltration and they will only contribute to surface runoff. Thus, 10% of Normal annual rainfall has been taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall has been deducted from the monsoon rainfall and balance rainfall is considered for computation of rainfall recharge. The same recharge factor is used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall is 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 has been estimated for normal rainfall, based on recent 30 to 50 years of data.

2.1.1.1.3.Percent Deviation

After computing the rainfall recharge for normal monsoon season rainfall using the ground water level fluctuation method and rainfall infiltration factor method these two estimates is compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the later is computed as

$$\boldsymbol{PD = \frac{R_{RF}(normal, wtfm) - R_{RF}(normal, rifm)}{R_{RF}(normal, rifm)} \times 100} \ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots.\ (\mathbf{14})$$

Where,

R_{RF} (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the ground water level fluctuation method

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

2.1.1.2. Recharge from Other Sources

Recharge from other sources constitutes recharges from canals, surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures in command areas where as in non-command areas it constitutes the recharge due to surface water irrigation, ground water irrigation, tanks & ponds and water conservation structures. The methods of estimation of recharge from different sources are used in the assessment as follows.

Sl. No.	Source	Estimation Formula	Parameters
1	Recharge from Canals	$R_C = WA \times SF \times Days$	R_C = Recharge from Canals WA = Wetted Area SF = Seepage Factor Days = Number of Canal Running Days
2	Recharge from Surface Water Irrigation	$R_{SWI} = AD \times Days \times RFF$	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	Recharge from Ground Water Irrigation	$R_{GWI} = GE_{IRR} \times RFF$	R_{GWI} = Recharge due to applied ground water irrigation GE_{IRR} = Ground Water Extraction for Irrigation RFF = Return Flow Factor
4	Recharge due to Tanks & Ponds	$R_{TP} = AWSA \times N \times RF$	R_{TP} = Recharge due to Tanks & Ponds AWSA = Average Water Spread Area N = Number of days Water is available in the Tank/Pond RF = Recharge Factor
5	Recharge due to Water Conservation Structures	$R_{WCS} = GS \times RF$	RWCS = Recharge due to Water Conservation Structures GS = Gross Storage = Storage Capacity multiplied by number of fillings. RF = Recharge Factor

2.1.1.3. Evaporation and Transpiration

Evaporation is estimated for the aquifer in the assessment unit if water levels in the aquifer are within the capillary zone. For areas with water levels within 1.0mbgl, evaporation is estimated using the evaporation rates available for other adjoining areas. If depth to water level is more than 1.0mbgl, the evaporation losses from the aquifer is taken as zero.

Transpiration through vegetation has been estimated if water levels in the aquifer are within the maximum root zone of the local vegetation. If water levels are within 3.5mbgl, transpiration is estimated using the transpiration rates available for other areas. If it is greater than3.5m bgl, the transpiration has been taken as zero.

2.1.1.4. Recharge During Monsoon Season

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

2.1.1.5. 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 & out of the sub unit and stream inflows & outflows during non-monsoon season is the total recharge/ accumulation during non-monsoon season for the sub unit. Similarly, this is to be computed for all the sub units available in the assessment unit.

2.1.1.6. Total Annual Ground Water Recharge

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

2.1.1.7. Annual Extractable Ground Water Resource (EGR)

The Annual Extractable Ground Water Resource (EGR) is computed by deducting the Total Annual Natural Discharge from Total Annual Ground Water Recharge.

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

2.1.1.8. Estimation of Ground Water Extraction

Ground water draft or extraction is assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

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

2.1.1.8.1. Ground Water Extraction for Irrigation (GE_{IRR})

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 (eg. 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.

***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.

2.1.1.8.2. Ground Water Extraction for Domestic Use (GE_{DOM})

There are several methods for estimation of extraction for domestic use(GEDOM). 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 extraction.

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

$$GE_{DOM} = Population \times Consumptive\ Requirement \times L_g \ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots. (16)$$

Where,

L_g = 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.

2.1.1.8.3. 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 is determined. Numbers of Industrial units which are dependent on ground water are multiplied with unit water consumption to obtain ground water extraction for industrial use.

$$\boldsymbol{GE_{IND} = Number\ of\ Industrial\ Units \times Unit\ Water\ Consumption \times L_g} \ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{17})$$

Where,

L_g = 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.

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.

2.1.1.9. Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

$$\boldsymbol{Stage\ of\ GW\ Extraction = \frac{Existing\ Gross\ GW\ Extraction\ for\ all\ Uses}{Annual\ Extractable\ GW\ Resources} \times 100} \ldots\ldots\ldots\ldots (\mathbf{18})$$

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.

2.1.1.10. Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. 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 prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. 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%	Significant decline in 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

2.1.1.11.Categorisation of Assessment Unit

2.1.1.11.1.Categorisation of Assessment Unit Based on Quantity

The categorisation 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

2.1.1.11.2.Categorisation of Assessment Unit Based on Quality

As it is not possible to categorize the assessment units in terms of the extent of quality hazard, based on the available water quality monitoring mechanism and database on ground water quality, 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. 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 has been tagged with the particular Quality hazard.

2.1.1.12.Allocation of Ground Water Resource for Utilisation

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 based on population has been 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. In situations where adequate data is not available to make this estimate, the following empirical relation has been utilized.

$$\boldsymbol{Alloc = 22 \times N \times L_g mm\ per\ year} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{19})$$

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 water supply (≤ 1.0)

2.1.1.13.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 is 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 has been projected as zero.

2.1.1.14. Additional Potential Resources under Specific Conditions

2.1.1.14.1. Potential Resource Due to Spring Discharge

Spring discharge occurs 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 has not been used for Categorisation. Spring discharge measurement has been 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.

$$\boldsymbol{Potential\ ground\ water\ resource\ due\ to\ springs = Q \times No.of days \ldots\ldots\ldots\ldots\ldots\ldots (20)}$$

Where,

Q = Spring Discharge

No of days = No of days spring yields.

2.1.1.14.2. Potential Resource in Waterlogged and Shallow Water Table Areas

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. The computation of potential resource to ground water reservoir in shallow water table areas has been done by adopting the following equation:

$$\boldsymbol{Potential\ groundwater\ resource\ in\ shallow\ water\ table\ areas = (5 - D) \times A \times S_Y \ldots\ldots\ldots (21)}$$

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

2.1.1.14.3. 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 resource from flood plain may be estimated on the same norms as for ponds, tanks and lakes. This has been calculated over the water spread area and only for the retention period using the following formula.

$$\textit{Potential groundwater resource in Flood Prone Areas} = \mathbf{1.4} \times \boldsymbol{N} \times \frac{\boldsymbol{A}}{\mathbf{1000}} \dots\dots\dots\dots\dots\dots\dots...(\mathbf{22})$$

Where,

N = No. of Days Water is Retained in the Area

A = Flood Prone Area

2.1.1.15. 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 has been 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 has been 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.

The total ground water resource of the block has been 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.

2.2. GROUND WATER ASSESSMENT IN URBAN AREAS

The Assessment of Ground Water Resources in urban areas is similar to that of rural areas. Because of the availability of draft data and slightly different infiltration process and recharge due to other sources, the following few points are to be considered.

- Even though the data on existing ground water abstraction structures are available, accuracy is somewhat doubtful and individuals cannot even enumerate the well census in urban areas. Hence the difference of the actual demand and the supply by surface water sources as the withdrawal from the ground water resources has been considered for the assessment.

- The urban areas are sometimes concrete jungles and rainfall infiltration is not equal to that of rural areas unless and until special measures are taken in the construction of roads and pavements. Hence, 30% of the rainfall infiltration factor has been taken into consideration for urban areas as an adhoc arrangement till field studies in these areas are done and documented field studies are available.
- Because of the water supply schemes, there are many pipelines available in the urban areas and the seepages from these channels or pipes are huge in some areas. Hence this component has been included in the other resources and the recharge has also been considered. The percent losses have been collected from the individual water supply agencies, 50% of which has been considered as recharge to the ground water system.
- In the urban areas in India, normally, there is no separate channels either open or sub surface for the drainage and flash floods. These channels also recharge to some extent the ground water reservoir. As on today, there is no documented field study to assess the recharge. The seepages from the sewerages, which normally contaminate the ground water resources with nitrate also contribute to the quantity of resources and hence same percent as in the case of water supply pipes has been taken as norm for the recharge on the quantity of sewerage when there is sub surface drainage system. If estimated flash flood data is available, the same percent has been used on the quantum of flash floods to estimate the recharge from the flash floods.
- Urban areas with population more than 10 lakhs, has been considered as urban assessment unit while assessing the dynamic ground water resources.

2.3. GROUND WATER ASSESSMENT IN WATER LEVEL DEPLETION ZONES

There are areas where ground water level shows a decline even in the monsoon season. The reasons for this may be any one of the following: (a) There is a genuine depletion in the ground water regime, with ground water extraction and natural ground water discharge in the monsoon season (outflow from the region and base flow) exceeding the recharge. (b) There may be an error in water level data due to inadequacy of observation wells.

If it is concluded that the water level data is erroneous, recharge assessment has been made based on rainfall infiltration factor method. If, on the other hand, water level data is assessed as reliable, the ground water level fluctuation method has been applied for recharge estimation. As ΔS in equation 3& 4 is negative, the estimated recharge will be less than the gross ground water extraction in the monsoon season. It must be noted that this recharge is the gross recharge minus the natural discharges in the monsoon season. The immediate conclusion from such an assessment in water depletion zones is that the area falls under the over-exploited category which requires micro level study.

2.4. NORMS HAS BEEN USED IN THE ASSESSMENT

2.4.1. Specific Yield

Recently under Aquifer Mapping Project, Central Ground Water Board has classified all the aquifers into 14 Principal Aquifers which in turn were divided into 42 Major Aquifers. Hence, it is required to assign Specific Yield values to all these aquifer units. The values recommended in the ***Table-2.1*** has been followed in the present assessments, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values

Table-2.1: Norms Recommended for Specific Yield

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Litho margic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	3	1	5
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	1.5	1	2
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	1.5	1	2
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	KarstifiedMiliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	Karstified Limestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
30	Limestone	LS03	Karstified Limestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	Karstified Limestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	Karstified Marble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	0.3	0.2	0.4
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	3	2	4
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

2.4.2. Rainfall Infiltration Factor

The values mentioned in ***Table-2.2*** has been used in the present assessment. The recommended Rainfall Infiltration Factor values has been used for assessment, unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values.

Table-2.2: Norms Recommended for Rainfall Infiltration Factor

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	22	20	24
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	22	20	24
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	22	20	24
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	22	20	24
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) -East Coast	Quaternary	16	14	18
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - West Coast	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	22	20	24
7	Alluvium	AL07	Glacial Deposits	Quaternary	22	20	24
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	7	6	8
9	Basalt	BS01	Basic Rocks (Basalt) - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered	Mesozoic to Cenozoic	7	6	8
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
11	Basalt	BS02	Ultra Basic - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
11	Basalt	BS02	Ultra Basic - Weathered	Mesozoic to Cenozoic	7	6	8
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	12	10	14
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	12	10	14
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	12	10	14
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	12	10	14
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	6	5	7
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	6	5	7
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	4	3	5
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	4	3	5
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	4	3	5
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	4	3	5
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	4	3	5
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	4	3	5
25	Limestone	LS01	Miliolitic Limestone	Quarternary	6	5	7

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	6	5	7
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	6	5	7
31	Limestone	LS04	Limestone with Shale	Proterozoic	6	5	7
33	Limestone	LS05	Marble	Azoic to Proterozoic	6	5	7
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	7	5	9
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	2	1	3
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	11	10	12
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	7	5	9
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
41	Schist	SC02	Phyllite	Azoic to Proterozoic	4	3	5
42	Schist	SC03	Slate	Azoic to Proterozoic	4	3	5
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	6	5	7
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	6	5	7
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	5	4	6

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	2	1	3
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	7	5	9
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	2	1	3
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	7	5	9
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	2	1	3
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	7	5	9
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	2	1	3
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
61	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre	Proterozoic to Cenozoic	7	6	8

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
			etc.) - Weathered, Jointed				
62	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3

2.4.3. Norms for Canal Recharge

The Norms suggested in ***Table-2.3*** has been used for estimating the recharge from Canals, where sufficient data based on field studies are not available.

.Table-2.3: Norms Recommended for Recharge due to Canals

Formation	Canal Seepage factor ham/day/million square meters of wetted area		
	Recommended	Minimum	Maximum
Unlined canals in normal soils with some clay content along with sand	17.5	15	20
Unlined canals in sandy soil with some silt content	27.5	25	30
Lined canals in normal soils with some clay content along with sand	3.5	3	4
Lined canals in sandy soil with some silt content	5.5	5	6
All canals in hard rock area	3.5	3	4

2.4.4. Norms for Recharge Due to Irrigation

The Recommended Norms are presented in ***Table-2.4***.

Table-2.4: Norms Recommended for Recharge from Irrigation

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non-paddy	Paddy	Non-paddy
≤ 10	45.0	25.0	50.0	30.0
11	43.3	23.7	48.3	28.7
12	40.4	22.1	45.1	26.8
13	37.7	20.6	42.1	25.0
14	35.2	19.2	39.3	23.3
15	32.9	17.9	36.7	21.7
16	30.7	16.7	34.3	20.3
17	28.7	15.6	32.0	18.9
18	26.8	14.6	29.9	17.6
19	25.0	13.6	27.9	16.4
20	23.3	12.7	26.0	15.3

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non-paddy	Paddy	Non-paddy
21	21.7	11.9	24.3	14.3
22	20.3	11.1	22.7	13.3
23	18.9	10.4	21.2	12.4
24	17.6	9.7	19.8	11.6
≥ 25	20.0	5.0	25.0	10.0

2.4.5. Norms for Recharge due to Tanks & Ponds

As the data on the field studies for computing recharge from Tanks & Ponds are very limited, for Seepage from Tanks & Ponds has been used as 1.4 mm / day in the present assessment.

2.4.6. Norms for Recharge due to Water Conservation Structures

The data on the field studies for computing recharge from Water Conservation Structures are very limited, hence, the norm recommended by GEC-2015 for the seepage from Water Conservation Structures is 40% of gross storage during a year which means 20% during monsoon season and 20% during non-monsoon Season is adopted.

2.4.7. Unit Draft

The methodology recommends to use well census method for computing the ground water draft. The norm used for computing ground water draft is the unit draft. The unit draft can be computed by field studies. This method involves selecting representative abstraction structure and calculating the discharge from that particular type of structure and collecting the information on how many hours of pumping is being done in various seasons and number of such days during each season. The Unit Draft during a particular season is computed using the following equation:

$$\boldsymbol{Unit\ Draft = Discharge\ in\ m^3/hr \times No.of\ pumping\ hours\ in\ a\ day \times No.of\ days} \dots\dots\dots (\mathbf{29})$$

But the procedure that is being followed for computing unit draft does not have any normalization procedure. Normally, if the year in which one collects the draft data in the field is an excess rainfall year, the abstraction from ground water will be less. Similarly, if the year of the computation of unit draft is a drought year the unit draft will be high. Hence, there is a requirement to devise a methodology that can be used for the normalization of unit draft figures. The following are the two simple techniques, which are followed for normalization of Unit Draft. Areas where, unit draft values for one rainfall cycle are available for at least 10 years second method shown in equation 31 is followed or else the first method shown in equation 30 has been used.

$$\boldsymbol{Normalised\ Unit\ Draft} = \frac{\boldsymbol{Unit\ Draft} \times \boldsymbol{Rainfall\ for\ the\ year}}{\boldsymbol{Normal\ Rainfall}} \dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots (\mathbf{30})$$

$$\boldsymbol{Normalised\ Unit\ Draft} = \frac{\sum_{i=1}^{n} \boldsymbol{Unit\ Draft_i}}{\boldsymbol{Number\ of\ Years}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(\mathbf{31})$$

2.5. INDIA -GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)

"INDIA-GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES) is a Software/Web-based Application developed by CGWB in collaboration with IIT-Hyderabad. It provides common and standardized platform for Ground Water Resource Estimation for the entire country and its pan-India operationalization (Central and State Governments). The system takes 'Data Input' through Excel as well as Forms, compute various ground water components (recharge, extraction etc.) and classify assessment units into appropriate categories (safe, semi-critical, critical and over-exploited). The Software uses GEC 2015 Methodology for estimation and calculation of Groundwater resources. It allows for unique and homogeneous representation of groundwater fluxes as well as categories for all the assessment units (AU) of the country.

URL of IN-GRES →http://ingres.iith.ac.in

CHAPTER 3

RAINFALL

The state of Nagaland enjoys sub-tropical to sub-montane temperate climate. The climate of the state varies to a great extent, even in places within a short distance. This variation in climate is mainly due to its physiography. There are basically four seasons, viz. Pre-monsoon, Monsoon or Rainy season, Autumn and Winter. The pre-monsoon season commences from March to May, characterized by rainfall, thunder storm and relatively high temperatures. During this period, the temperature varies from 12ºC to 34ºC. The rainy season commences with the onset of southwest monsoon during June and lasts up to September. This encourages a lot of wet cultivation in the state. Then, it is followed by short autumn from mid-October to November, which also indicates the slow retreating of monsoon with clear and sunny sky. The winter season commences from December to the end of February. This is the coldest season of the year with sharp decline in the temperature. During this period the state experiences very cold nights with temperature varying from 4° to 28°C. Winter months are basically dry with reducing diurnal range of temperature.

There are 15 nos. of Meteorological observatories spread all over the state located in altitudes varying from 160 m to 1780 m a MSL. Average annual rainfall of Nagaland varies from 423.7 to 2621.6 mm. Average monsoon rainfall varies from 921 to 1507 mm. Monsoon rainfall comprise 65 to 82% of average annual rainfall.

Table 3.1: District wise Normal Rainfall, Actual Rain fall during Ground Water Assessment Year 2023-24

District	Year	Monsoon		Non-Monsoon	
		Actual (mm)	Normal (mm)	Actual (mm)	Normal (mm)
Dimapur	2023-2024	1017.38	1400.4	288.78	344.56
Kiphire	2023-2024	1458.64	703.1	330.75	371.0
Kohima	2023-2024	1211.52	1400.4	305.77	378.9
Longleng	2023-2024	1542.7	1508.5	390.03	371.0
Mokokchung	2023-2024	1558.17	1508.5	363.78	571.9
Mon	2023-2024	1515.39	1112.6	498.76	356.5
Peren	2023-2024	924.74	1015.3	266.1	378.9
Phek	2023-2024	1241.38	924.1	310.37	371.0
Tuensang	2023-2024	1580.97	1508.5	361.0	571.0
Wokha	2023-2024	1564.48	1601.4	353.34	565.36
Zunheboto	2023-2024	1528.87	1508.5	335.58	571.9

CHAPTER 4

HYDROGEOLOGICAL SETUP OF NAGALAND

Hydrogeological condition of the state is mainly controlled by two distinct formations, i.e., semi-consolidated and unconsolidated formations. The semi-consolidated formations gradually experiencing more rigidness from north to south and the unconsolidated formations attaining maturity from south to north.

The semi-consolidated rocks belong to Tertiary age range from Eocene to Pleistocene (Disang to Dihing). The Lower Tertiary formation is confined to south-central and occupies the state fully with formations of moderate to high hills and adjoining narrow valleys along strike direction of hills. These forms basically run-off zone. Infiltration to ground water is low to moderate. The Upper Tertiary group of rocks, i.e., Surma Group to Dihing are exposed mainly in the northern part of the state which continues to Assam border. These formations form low to moderate altitude hill ranges with structural valleys following the strike of the hills. The rocks comparatively show less consolidation than the Lower Tertiary. This zone is also basically a run-off zone with moderate to low infiltration.

The structural valleys comprise unconsolidated sediments, with variable thickness, show moderate to high infiltration, less run-off and recharge condition. Intermontane valleys are suitable for ground water development through construction of dug wells and tube wells.

Movement and occurrence of ground water in consolidated formation is controlled by secondary porosity like joints, faults etc. Yield is expected to be moderate to good along the fractures where intersection of more than one set of fractures and joints are present.

Consolidated formation, constitute of ultrabasic and basic rocks which occupies a small area towards south-eastern border has not yet been studied.

Ground water conditions in hills and valleys

In the hilly area, the factors governing the ground water occurrence, availability and extent are – lithology, geomorphology, gradient and tectonic activity.

Rock formations in the area are of semi-consolidated nature with varied physical identity. Tectonic effect on these formations promoted large scale denudational activity and present rugged undulating scenario. Structural elements i.e. lineaments developed in the area are mainly in NE-SW to NNE-SSW direction and also in NW-SE and E-W direction. Majority of hills are with more than 20% slope and act as high run-off zone.

In the hilly area ground water manifests as springs at different contour levels. However, though most of the springs are of ephemeral nature, it shows meager flow during lean period. These springs are found to develop in 1^{st} and 2^{nd} order streams. High discharge springs are also not uncommon. In south-central part of the hilly area, splintery shales of Disang series are predominant which can be classified as low to medium potential zone.

Ground water potential in fractured zone, caused by tectonic activities are likely to prove successful in hills. In valley area, ground water occurrence and potential is likely to show individual character within the structural limit. Moreover, all the valley formations are within the Schuppen zone which play vital role in dispositional criteria of litho-types. Principle Aquifers of Nagaland is given in Fig 1.

3.1 Aquifer System:

The aquifer system in the state can be divided as a two aquifer systems, viz., first aquifer (shallow) and second aquifer (deeper). Shallow or first aquifer consists of weathered residuum where ground water occurs under water table condition and is mainly developed through construction of dug wells. The second aquifer is the deeper aquifer which tapped the fractured zone and is mainly developed through borewells. Based on the study of litholog and analysis of depth of construction of dug wells and bore wells, it is found that the first aquifer occur within depth of 20 to 50m. Ground water in the second aquifer occurs under unconfined to semi-confined in the alluvial & fractures upto the maximum explored depth of 200m. Principal aquifer system of the state is presented in **Fig.1.**

An area of 910 sq km in Dimapur district of Nagaland was covered under National Aquifer mapping Programme as per the Annual Action Plan 2012-13 and 2017-18 of Central Ground Water Board, North Eastern Region, Guwahati. The main objective of the study is to delineate the horizontal and vertical disposition of aquifer as well as to study the aquifer character. To know the aquifer disposition in the study area, exploratory wells data, VES data available with CGWB and some data of state departments, Govt. of Nagaland were utilized.

In Dimapur valley, CGWB has drilled 11 EWs within a depth range of 100 to 301 m. A thin layer of discontinuous clay beds occurs at surface all over the alluvial deposit ranging in thickness from 5 to 10 m. The tube wells drilled in alluvial deposits show alternate thick beds of sand, gravel and thin beds of clay.

The exploration reveals prevalence of both unconsolidated rocks belonging to Recent to Sub-Recent and semi-consolidated rocks belonging to Upper Tertiary age. Thickness of alluvium ranges from less than 10 m to maximum of 50 m, increasing towards north-eastern part of the valley. The Tertiary sediments comprise of clay, soft sandstone, siltstone, friable ferruginous sandstone, pebble/boulder agglomerate, and clay etc within 300 m depth.

It can be deciphered from the litholog of different exploratory wells drilled by CGWB that two aquifer system exists in the area. Within a depth of 50m an unconsolidated sandy aquifer with gravel and clay intercalations exist in places. This aquifer is comprised mainly of medium to coarse sand. Upper Tertiary sandstone aquifer occurs within a depth range of 50 to 200m. In some places due to the presence of clay intercalations 2 to 4 granular zones occur in the study area. Separations of two or more granular zones by clay beds often misguide to classify the aquifers into a multiple aquifer system. However, these clay beds are mostly in lensoid shape and they pinch out within a short distance. Thickness of the saturated zone varies from 8 to 46 m within a depth range of 50 m, 10 to 64 m within a depth range of 100 m, 8 to 57 m within a depth range of 200 m and up to 47 m within a depth range of 300 m. The deep tube wells constructed by CGWB show yield of 3.12 to 61.5 m^3/hr for a drawdown of 3.5 to 30.2 m. Transmissivity varies from 4.75 to 301 m^2/day. Hydraulic conductivity varies from 0.07 to 6.05 m/day. Storage co-efficient varies from 1.5 x 10^{-3} to 3.8 x 10^{-4}.

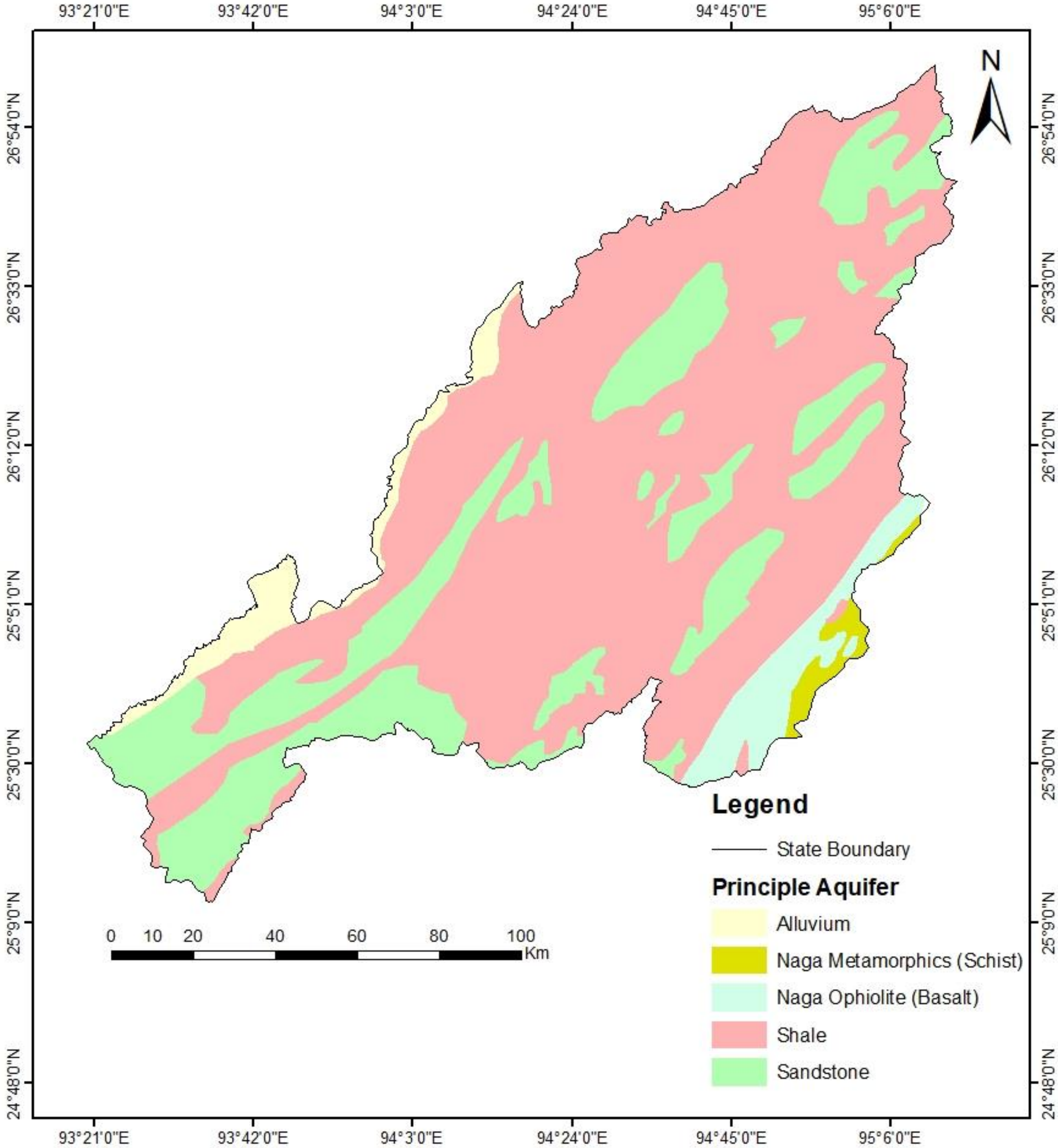

Fig:1. Principal Aquifer System of Nagaland.

CHAPTER-5

GROUND WATER LEVEL SCENARIO IN NAGALAND

5.1 Groundwater Level Scenario (2023)

Groundwater level data of pre-monsoon (March 2023)

During the month of March 2023, monitoring work in Nagaland state was taken up in Dimapur district only. In the district, three stations recorded water level in the range of 2-5mbgl. Most of the monitoring stations (40%, 4 nos.) recorded water level in the range of 5-10mbgl. In 3(30%) stations water level was observed in the range of 10-20 mbgl range. The minimum and maximum water levels of 2.21 magl and 13.56 mbgl had been recorded in stations located at Dimapur District, Nagaland.The depth to water level in the state during pre-monsoon period has been presented in Fig.2.

Groundwater level data for post-monsoon 2023

During November 2023, water level in the state was monitored only in Dimapur district. Water level was recorded in 60% (6) stations in the range of 2-5 mbgl, in 30% (3) stations in the range of 5-10 mbgl and in 1 (10%) station in the range of 10-20 mbgl. The minimum and the maximum water level had been observed as 2.25 mbgl and 11.51 mbgl respectively.

The depth to water levels in the state during pre-monsoon and post period has been presented in Table 5.1 and depicted in Fig.2 and Fig.3.

Table 5.1: Depth to ground water level during the year, 2023.

Location	Station No.	Station Type (Dug Well/ Borewell/Tube Well)	Depth to Water Level (mbgl)	
			March-2023	November-2023
Dimapur				
3 Mile Bazar	NLDM19	Dug Well	2.780	-
7th Mile Colony	NLDM21	Dug Well	11.890	8.150
Chumkidima	83G1D1	Dug Well	3.520	2.250
Diphupar	NLDM22	Dug Well	10.610	2.780
Doyabur DMC	NLDM12	Dug Well	6.340	3.020
Maibiram	NLDM13	Dug Well	8.290	7.000
Marwari Colony	83G1C9	Dug Well	2.210	5.580
Rilayan Colony	NLDM24	Dug Well	13.560	11.510
Seirujha Colony	83G9GM11	Dug Well	7.250	4.010
Singrijan	83G1C6	Dug Well	6.750	3.720
Zakesatho Colony	NLDM23	Dug Well	-	2.780

5.1.0 Fluctuation of Groundwater Level:

Comparison of Pre-monsoon 2023 to Pre-monsoon 2022 (**Fig.**4)

In Nagaland, comparison of water level of March 2023 with that of March 2022 indicate rise during March 2023 in 44.44% (4) of monitored stations and 55.56% (5) stations show falling trend. In 33.34 % (3) stations fall was recorded in the range of 0-2m and in 11.11% (1) station in the range of 2-4 m and 11.11 % (1) station in above 4 m, while the rise had been recorded in 1 (11.11%) in the range of 0-2 m and in 11.11% (1) stations within the range of 2-4 m and 22.22% (1) station beyond 4m.

Comparison of November 2023 to November 2022 (Fig.5)

In Nagaland, analyses of 10 stations was done located in Dimapur district. During November 2023, fall in water level was recorded in 80% (8) monitored stations and rise in 20% (2) stations during November 2023. No rise beyond 4m was recorded. 1 (10%) station each recorded rise in 0-2 m and 2-4 m respectively. Fall beyond 4m was recorded in 2 (20%) stations and fall within 2-4 m was recorded in 2 (20%) stations . Fall within 0-2 m was recorded in 4 (40%) stations.

Comparison of Pre-Monsoon 2023 with decadal mean of Pre-Monsoon (2013 to 2022) (Fig.6)

The analysis of water levels of stations located in Dimapur district reveals that 3 (50%) stations recorded rise and 3(50%) stations recorded fall during March 2023 in comparison to decadal mean data of preceding years. Most of the fall and rise have been recorded within 4 m. The rise ranged from 0.67 m to 3.8 m and the fall ranged from 0.99 m to 4.3 m.

Comparison of Post-Monsoon 2023 with decadal mean of Post-Monsoon (2013 to 2022),(Fig.7)

Ten stations of Dimapur district were analysed for November 2023. Comparison of November 2023 water level with mean water level data of the same period of preceding 10 years indicated both rise and fall in water level. Rise in the ranges of 0-2 m was observed in 50% (5) stations. Fall in the range of 0-2 m was found in 4 (40%) stations and in one station in the range of 2- 4 m. Maximum rise and maximum fall were recorded as 1.79 m and 2.35 m.

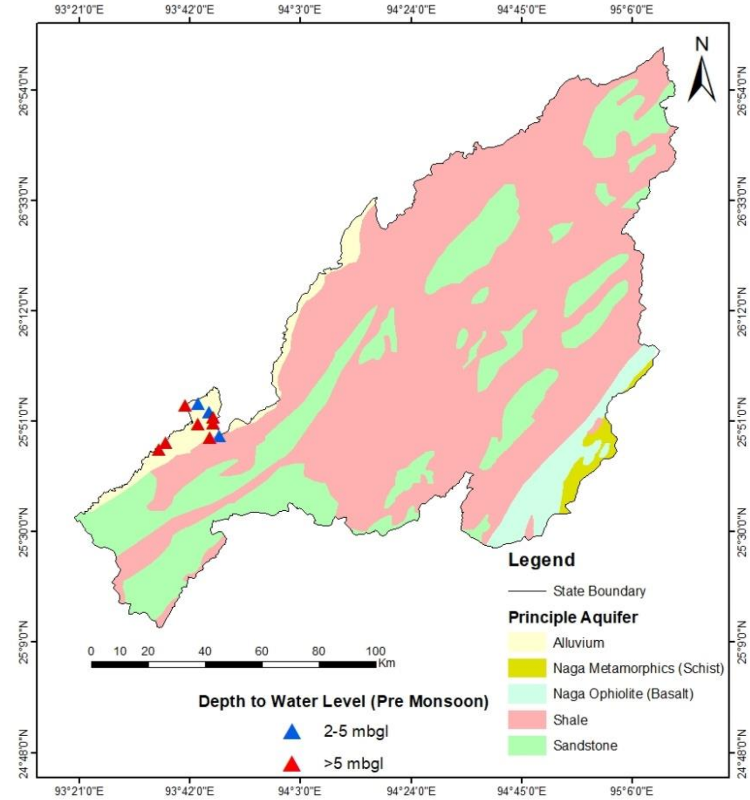

Fig.2: Depth to water level of Nagaland during Pre-monsoon (March, 2023) period.

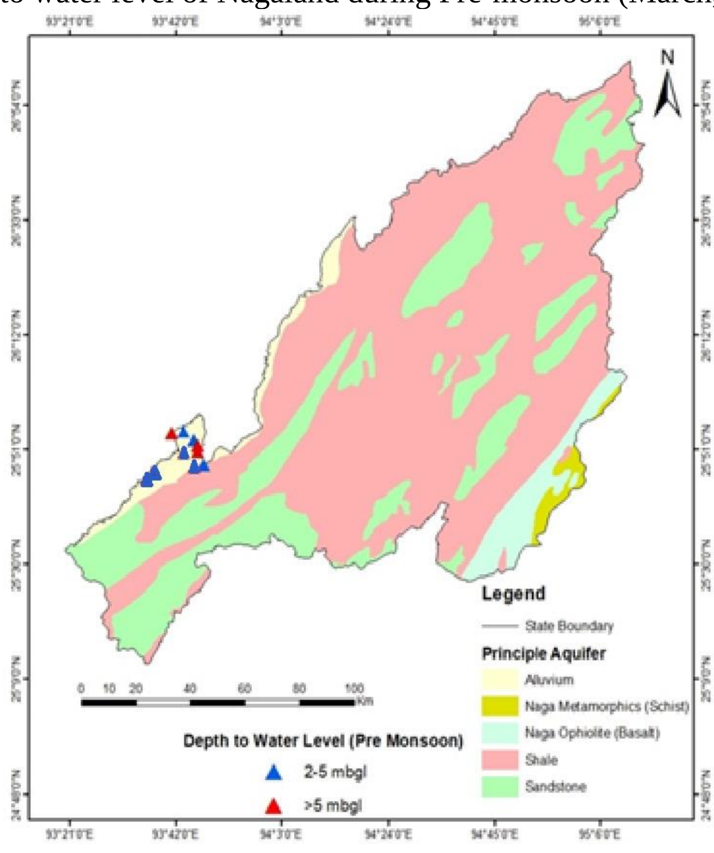

Fig.3: Depth to water level of Nagaland during Post monsoon (November, 2023) period.

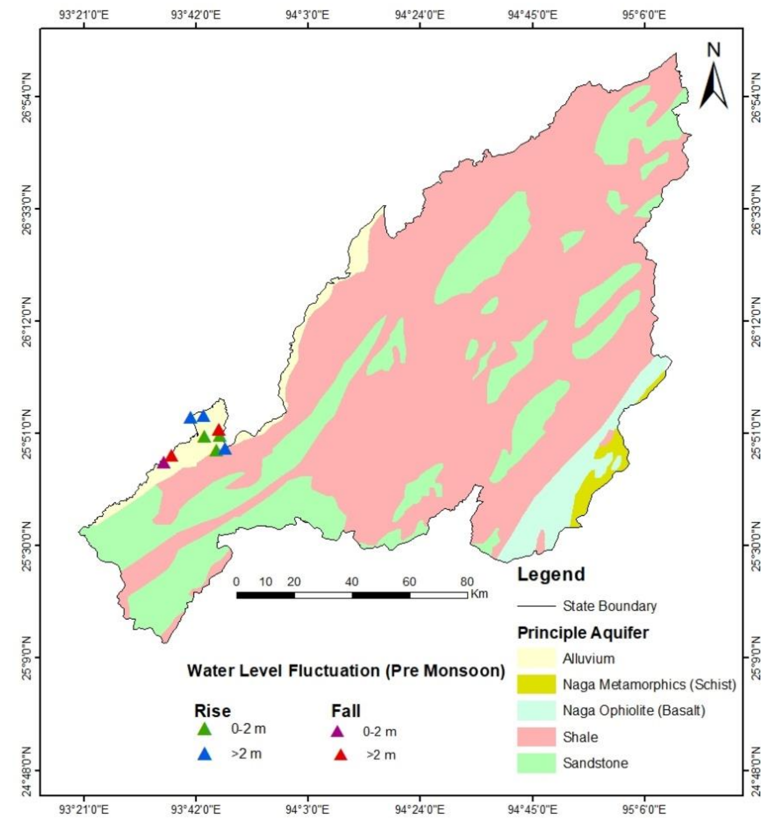

Fig.4: Ground water level fluctuation in Nagaland during Pre-monsoon, 2023 (March) with pre-monsoon , 2022.

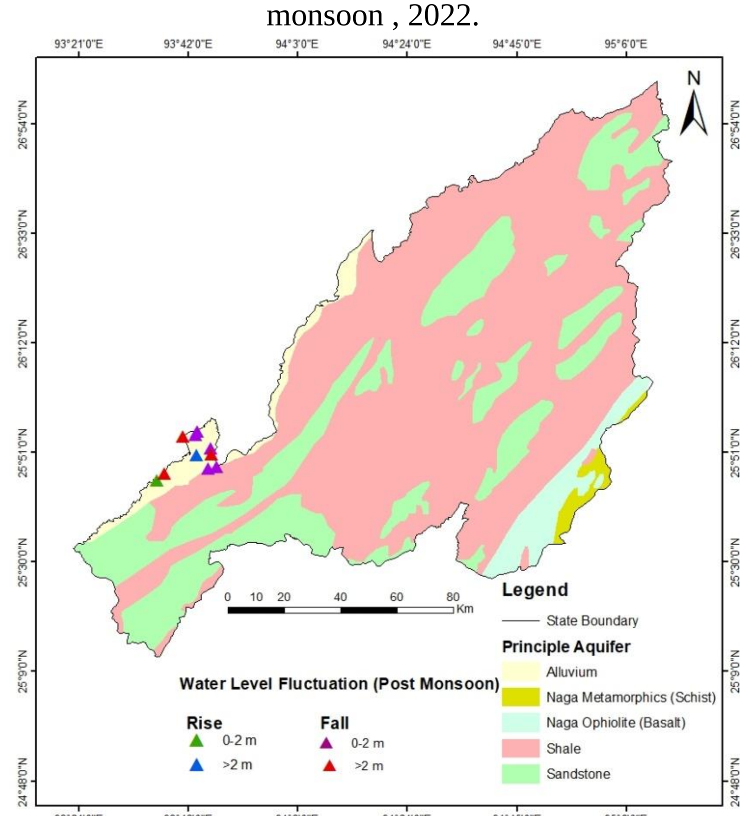

Fig.5: Ground water level fluctuation in Nagaland during Post monsoon, 2023 (November) with Post monsoon , 2022.

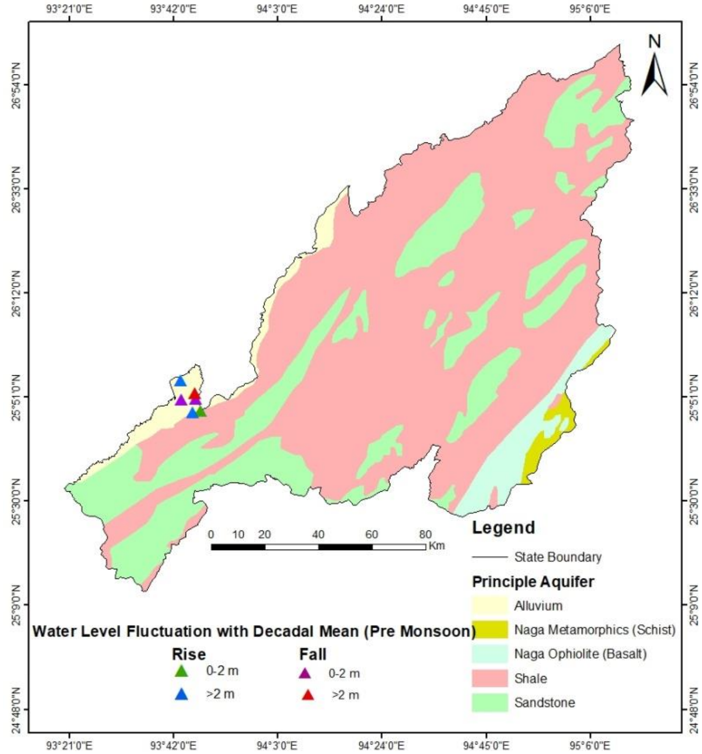

Fig.6: Ground water level fluctuation in Nagaland during Pre- monsoon, 2023(March) with Decadal Mean (March, 2013-2022)

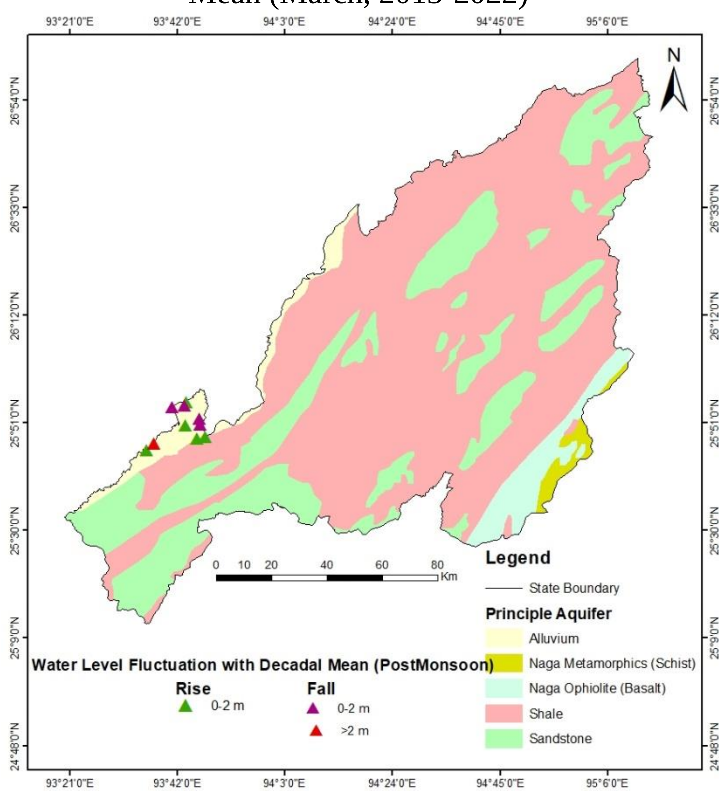

Fig.7: Ground water level fluctuation in Nagaland during Post monsoon, 2023 (November) with Decadal Mean (November, 2013-2022)

CHAPTER 6

GROUND WATER RESOURCES OF NAGALAND

Total ground water recharge is 0.62 BCM and Annual extractable groundwater resources is 0.56 BCM after deducting natural discharge and resultant flow. Ground water extraction for various uses has been estimated for all the assessment units of Nagaland. Gross annual ground water extraction for all uses is 0.03 BCM. Balance groundwater availability for future use is 0.53 BCM. The stage of groundwater extraction is 4.72 % and all the 52 assessment units in Nagaland state falls under **SAFE** category.

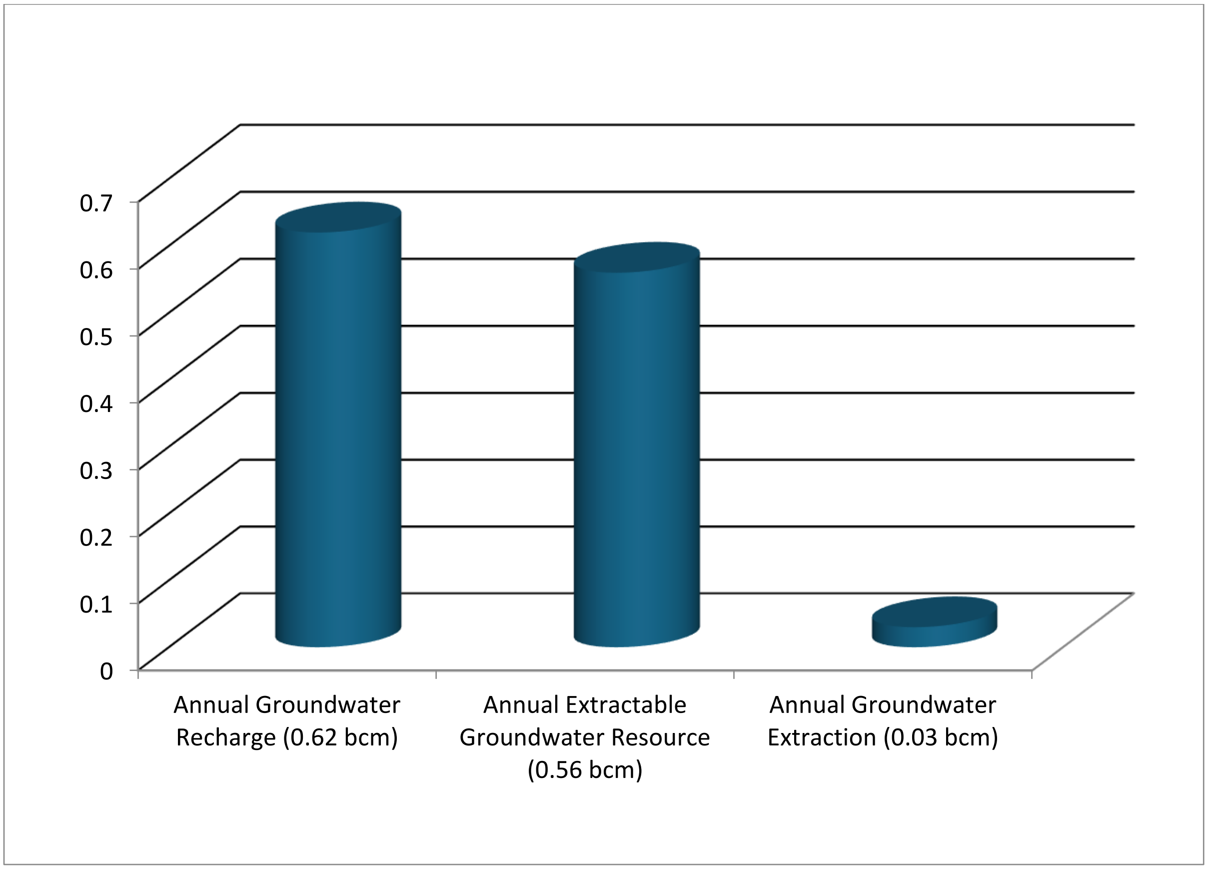

Fig:8 Dynamic Ground water Recourses Scenario 2024– Nagaland

6.1. COMPARISON WITH PREVIOUS ASSESSMENT

Sl. No.	ITEM	Year 2022-23	Year 2023-24	COMPARISON
	Estimation	**INGRES**	**INGRES**	
1	**Total Annual Ground Water Recharge (BCM)**	0.60	**0.62**	Increase by 0.02

2	**Annual Extractable Ground Water Resources (BCM)**	0.54	**0.56**	Increase by 0.02
3	**Irrigation extraction (BCM)**	0.002	**0.01**	Increase by 0.008
4	**Industrial extraction (BCM)**	0	**0**	
5	**Domestic extraction (BCM)**	0.02	**0.02**	
6	**Stage of GW Extraction (%)**	3.75	**4.72**	Increase by 0.97
7	**Provision for Domestic use (BCM)**	0.02	**0.02**	
8	**GW availability for future use (BCM)**	0.52	**0.53**	0.01
9	**No. of SAFE Units**	52	**52**	
10	**No. of O.E. Units**	0	**0**	
11	**No. of Dark/ Critical units**	0	**0**	

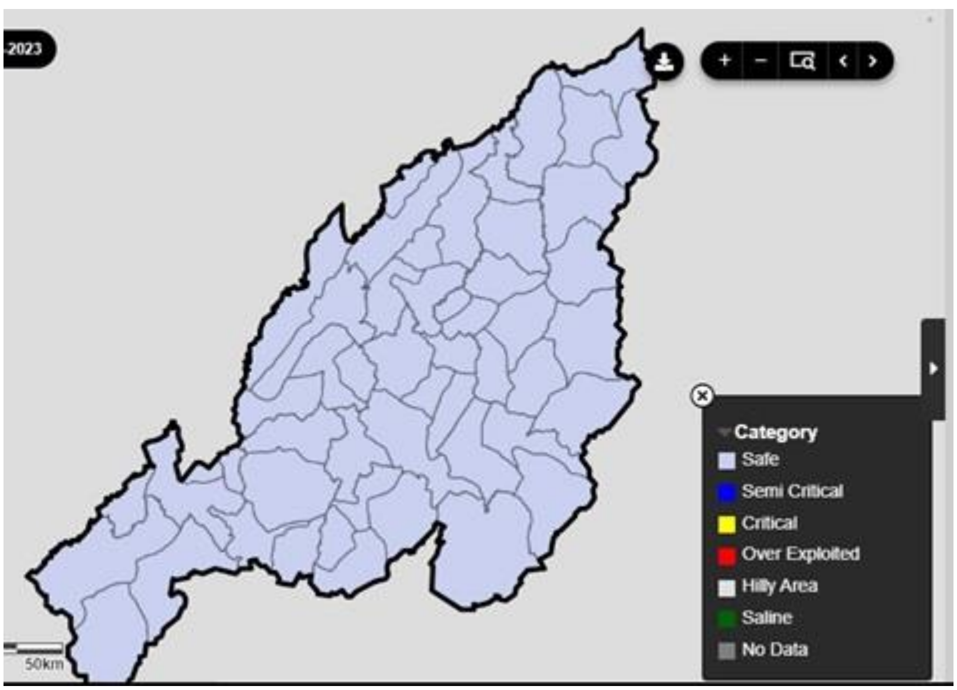

Fig:9 Categorization Map of Nagaland

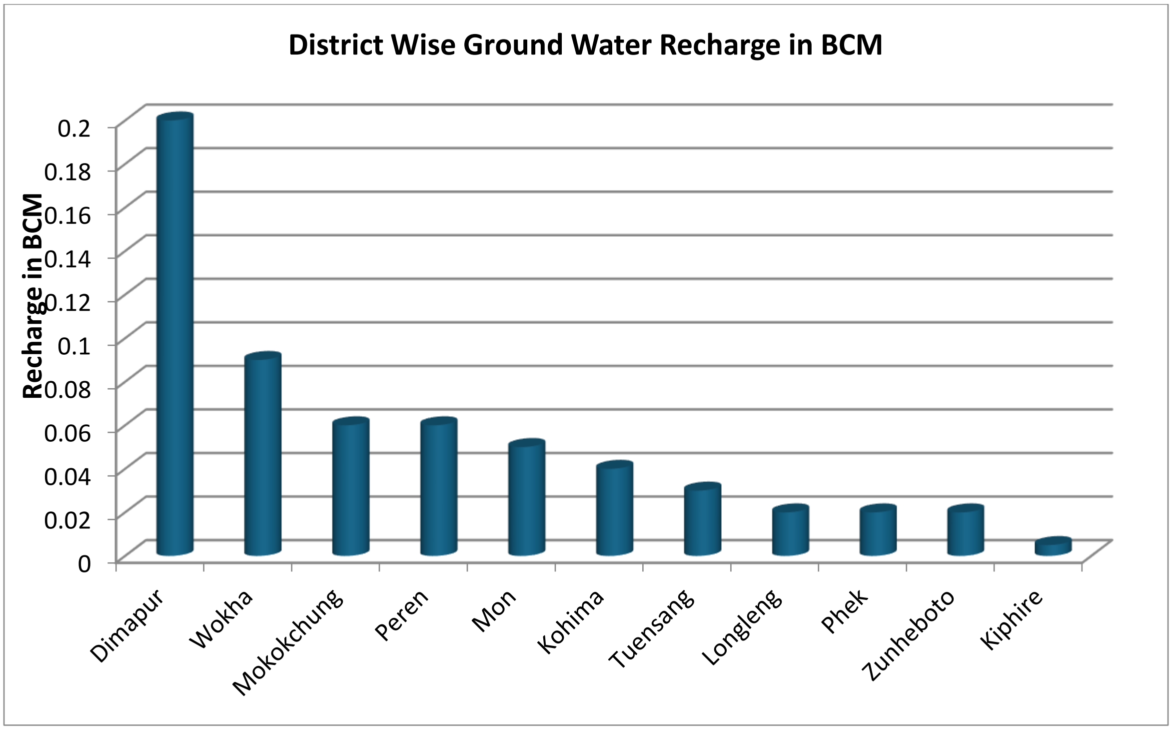

Fig: 10 Bar Diagram showing District wise Ground Water Recharge of Nagaland

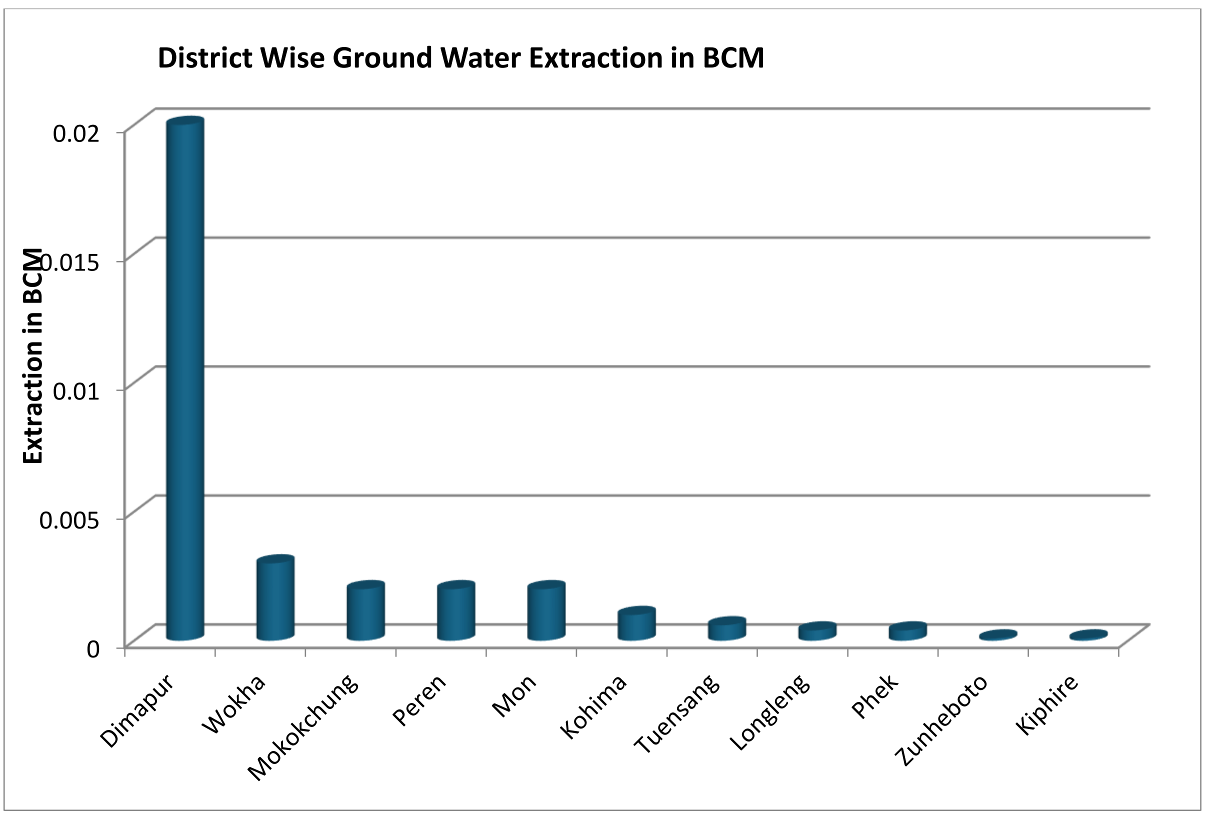

Fig: 11 Bar Diagram showing District wise Ground Water Extraction of Nagaland.

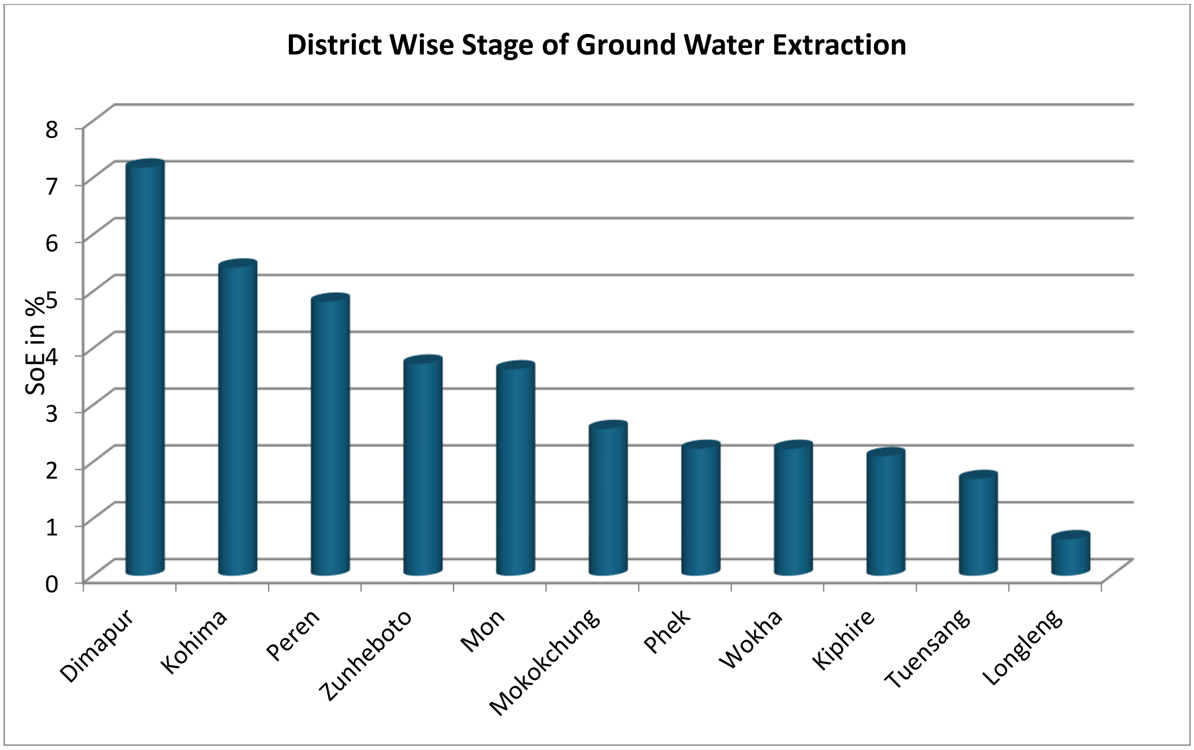

Fig:12 Bar Diagram showing District wise Stage of Extraction of Nagaland.

CHAPTER 7

CONCLUSION

Ground water in the state is primarily controlled by lithology, structure and also by physiography. Ground water mainly occurs under unconfined to semi-confined condition in both consolidated and unconsolidated formation.

In the present assessment, the Ground water resources have been assessed block-wise. The Total Annual Ground Water Recharge of the State has been assessed as 0.62 BCM and Annual Extractable Ground Water Resources as 0.56 BCM. The current Annual Ground Water Extraction is 0.03 BCM and Stage of Ground Water Extraction is 4.72 %. All the 52 assessment units have been categorized as ‘Safe’.

Similarly, out of 3855.07 sq km recharge worthy area of the State, 3855.07 sq km (100 %) under ‘Safe’ categories of assessment units. Out of total 0.56 bcm annual extractable ground water resources of the State, 0.56 bcm (100 %) are under ‘Safe’ categories of assessment units.

As compared to 2023 assessment, the Annual Ground Water Recharge has increased from 0.60 to 0.62 bcm, Annual Extractable Ground Water Resources has increased from 0.54 to 0.56 BCM. The reason can be attributed to increase in recharge from rainfall and other sources. The Ground Water Extraction has increased minutely. Therefore, Stage of ground water extraction has slightly increased from 4.60 % to 4.72 %.

Annexure-I

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024

NAGALAND

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			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	NAGALAND	0.41	0.12	0.08	0.01	0.62	0.05	0.56	0.01	0	0.02	0.03	0.02	0.53	4.72
	Total (bcm)	0.41	0.12	0.08	0.01	0.62	0.05	0.56	0.01	0	0.02	0.03	0.02	0.53	4.72

Annexure-II

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024

NAGALAND

S.NO	Name of District	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	Dimapur	19261.31	1409.54	2358.73	192.64	23222.22	1649.91	21572.31	737.83	2.38	808.36	1548.56	859.22	19972.88	7.18
2	Kiphire	127.82	327.36	56.57	0.27	512.02	51.2	460.82	0	0	9.66	9.66	10.42	450.39	2.1
3	Kohima	2073.08	1838.23	340.8	101.54	4353.65	435.36	3918.29	0	0.2	212.36	212.56	224.74	3693.34	5.42
4	Longleng	1021.28	334.07	141.57	6.32	1503.24	150.32	1352.92	0	0	8.67	8.66	15.65	1337.28	0.64

5	**Mokokchung**	4294.87	775.47	1201.67	19.03	6291.04	629.1	5661.94	82.74	0	63.52	146.25	64.31	5514.91	2.58
6	**Mon**	3564.12	286.4	773.54	6.14	4630.2	463.02	4167.18	10.99	0.34	139.77	151.1	140.02	4015.82	3.63
7	**Peren**	3354.89	1695.14	917.28	63	6030.31	603.04	5427.27	183	0	78.58	261.57	79.47	5164.8	4.82
8	**Phek**	539.15	1141.93	163.85	16.33	1861.26	186.13	1675.13	0	0	37.33	37.33	38.17	1636.96	2.23
9	**Tuensang**	789.97	1871.5	220.51	0.26	2882.24	288.23	2594.01	0	0	43.99	43.99	44.55	2549.46	1.7
10	**Wokha**	5560	1615.41	1400.05	100.69	8676.15	867.62	7808.53	5.21	0.29	168.32	173.82	169.75	7633.27	2.23
11	**Zunheboto**	701.11	813.02	196.18	44.74	1755.05	175.51	1579.54	0	0.36	58.52	58.89	58.66	1520.51	3.73
	Total (Ham)	41287.6	12108.07	7770.75	550.96	61717.38	5499.44	56217.94	1019.76	3.57	1629.07	2652.39	1704.96	53489.62	4.72
	Total (Bcm)	0.41	0.12	0.08	0.01	0.62	0.05	0.56	0.01	0	0.02	0.03	0.02	0.53	4.72

Annexure-III(A)

Catagorization 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	**NAGALAND**	52	52	100	-	-	-	-	-	-	-	-	
	Total	52	52	100	-	-	-	-	-	-	-	-	
	Grand Total	52	52	100	-	-	-	-	-	-	-	-	

Annexure III (B)

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024													
NAGALAND													
S.No	**Name of District**	**Total No. of Assessed Units**	**Safe**		**Semi-Critical**		**Critical**		**Over-Exploited**		**Saline**		
			No	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	
1	**Kiphire**	3	3	100.0	-	-	-	-	-	-	-	-	
2	**Zunheboto**	6	6	100.0	-	-	-	-	-	-	-	-	
3	**Wokha**	5	5	100.0	-	-	-	-	-	-	-	-	
4	**Kohima**	4	4	100.0	-	-	-	-	-	-	-	-	

5	**Longleng**	2	2	100.0	-	-	-	-	-	-	-	-
6	**Mon**	6	6	100.0	-	-	-	-	-	-	-	-
7	**Peren**	3	3	100.0	-	-	-	-	-	-	-	-
8	**Phek**	5	5	100.0	-	-	-	-	-	-	-	-
9	**Dimapur**	4	4	100.0	-	-	-	-	-	-	-	-
10	**Tuensang**	8	8	100.0	-	-	-	-	-	-	-	-
11	**Mokokchung**	6	6	100.0	-	-	-	-	-	-	-	-
	Total	52	52	100.0	-	-	-	-	-	-	-	-

Annexure III (C)

ANNUAL EXTRACTABLE RESOURCE OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES, 2024

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	**NAGALAND**	562.18	562.18	100	-	-	-	-	-	-	-	-
	Total	562.18	562.18	100	-	-	-	-	-	-	-	-
	Grand Total	562.18	562.18	100	-	-	-	-	-	-	-	-

Annexure- III (D)

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024

NAGALAND

S.No	Name of District	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	**Kiphire**	4.61	4.61	100	-	-	-	-	-	-	-	-
2	**Zunheboto**	15.8	15.8	100	-	-	-	-	-	-	-	-
3	**Wokha**	78.09	78.09	100	-	-	-	-	-	-	-	-
4	**Kohima**	39.18	39.18	100	-	-	-	-	-	-	-	-
5	**Longleng**	13.53	13.53	100	-	-	-	-	-	-	-	-

6	**Mon**	41.67	41.67	100	-	-	-	-	-	-	-	-
7	**Peren**	54.27	54.27	100	-	-	-	-	-	-	-	-
8	**Phek**	16.75	16.75	100	-	-	-	-	-	-	-	-
9	**Dimapur**	215.72	215.72	100	-	-	-	-	-	-	-	-
10	**Tuensang**	25.94	25.94	100	-	-	-	-	-	-	-	-
11	**Mokokchung**	56.62	56.62	100	-	-	-	-	-	-	-	-
	Total	562.18	562.18	100	-	-	-	-	-	-		
	Grand Total	562.18	562.18	100	-	-	-	-	-	-		

Annexure- III (E)

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	**NAGALAND**	16579	3855.07	3855.07	100	-	-	-	-	-	-	-	-
	Total	16579	3855.07	3855.07	100	-	-	-	-	-	-	-	-
	Grand Total	16579	3855.07	3855.07	100	-	-	-	-	-	-	-	-

Annexure III (F)

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024													
NAGALAND													
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	**Kiphire**	35.76	35.76	100.0	-	-	-	-	-	-	-	-
2	**Zunheboto**	89.85	89.85	100.0	-	-	-	-	-	-	-	-
3	**Wokha**	669.21	669.21	100.0	-	-	-	-	-	-	-	-
4	**Kohima**	282.64	282.64	100.0	-	-	-	-	-	-	-	-
5	**Longleng**	128.9	128.9	100.0	-	-	-	-	-	-	-	-
6	**Mon**	615.12	615.12	100.0	-	-	-	-	-	-	-	-
7	**Peren**	638.38	638.38	100.0	-	-	-	-	-	-	-	-

8	**Phek**	113.09	113.09	100.0	-	-	-	-	-	-	-	-
9	**Dimapur**	630.46	630.46	100.0	-	-	-	-	-	-	-	-
10	**Tuensang**	101.23	101.23	100.0	-	-	-	-	-	-	-	-
11	**Mokokchung**	550.43	550.43	100.0	-	-	-	-	-	-	-	-
	Total	3855.07	3855.07	100.0	-	-	-	-	-	-	-	-

Annexure IV (A)

CATEGORISATION OF ASSESSMENT UNIT, 2024							
NAGALAND							
S.NO	**Name of District**	**S.NO**	**Name of Semi-Critical Assessment Units**	**S.NO**	**Name of Critical Assessment Units**	**S.NO**	**Name of Over-Exploited Assessment Units**
ABSTRACT							
Total No. of Assessed Units		**Number of Semi critical Assessment Units**		**Number of Critical Assessment Units**		**Number of Over Exploited Assessment Units**	
0		**0**		**0**		**0**	

Annexure IV (B)

QUALITY PROBLEMS IN ASSESSMENT UNITS, 2024							
NAGALAND							
S.NO	**Name of District**	**S.NO**	**Name of Assessment Units affected by Fluoride**	**S.NO**	**Name of Assessment Units affected by Arsenic**	**S.NO**	**Name of Assessment Units affected by Salinity**
ABSTRACT							
Total No. of Assessed Units		**Number of Assessment Units affected by Fluoride**		**Number of Assessment Units affected by Arsenic**		**Number of Assessment Units affected by Salinity**	
0		0		0		0	

Annexure IV (C)
List of Saline Assessment units - Nil
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	NAGALAND	0	0	52

Annexure V (B)

COMPARISON OF CATEGORIZATION OF ASSESSMENT UNITS (2023 AND 2024)									
NAGALAND									
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
IMPROVED									
NIL									
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
DETERIORATED									
NIL									

Annexure VI
Assessment Unit Wise Report (Attribute Table)

Sl. No	District	Assessment Unit Name	Total Geographical Area	Recharge Worthy Area	Recharge from Rainfall-MON	Recharge from Other Sources-MON	Recharge from Rainfall-NM	Recharge from Other Sources-NM	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Irrigation Use (Ham)	Industrial Use (Ham)	Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/Semicritical/Safe)	Bo_Aquifer
1	Kiphire	Simiti	31080	1160.81	41.49	164.64	18.36	0.12	224.61	22.46	202.15	0	0	3.12399314	3.12	3.37	198.78	1.54340836	safe	0
2	Kiphire	Kiphire	25420	1043.61	37.3	80.43	16.51	0.06	134.3	13.43	120.87	0	0	6.10925923	6.11	6.59	114.28	5.05501779	safe	0

3	Kiphire	Pungro	56500	1371.78	49.03	82.29	21.7	0.09	153.11	15.31	137.8	0	0	0.42261675	0.43	0.46	137.33	0.31204644	safe	0
4	Zunheboto	Suruhoto	12024	765.26	59.71	118.23	16.71	4.94	199.59	19.96	179.63	0	0	5.81982545	5.82	5.83	173.8	3.23999332	safe	0
5	Zunheboto	Ghathashi	23100	1901.65	148.38	53.1	41.52	2	245	24.5	220.5	0	0	5.36748218	5.37	5.38	215.12	2.43537415	safe	0
6	Zunheboto	Satakha	38774	2093.25	163.33	168.69	45.7	7.88	385.6	38.56	347.04	0	0	9.65414027	9.66	9.68	337.35	2.7835408	safe	0
7	Zunheboto	Akuluto	26974	2703.28	210.93	86.27	59.02	3.1	359.32	35.93	323.39	0	0	7.85215935	7.85	7.87	315.52	2.42740963	safe	0
8	Zunheboto	Tokiye	14966	905.94	70.69	167.1	19.78	7.07	264.64	26.47	238.17	0	0	9.56836679	9.57	9.59	228.58	4.0181383	safe	0
9	Zunheboto	Zunheboto	9662	616.09	48.07	219.63	13.45	19.75	300.9	30.09	270.81	0	0.36	20.2588525	20.62	20.31	250.14	7.61419445	safe	0
10	Wokha	Chukitong	14534	4922.78	409	90	102.99	6.64	608.63	60.86	547.77	0	0	3.85421627	3.86	3.89	543.87	0.70467532	safe	0
11	Wokha	Wozhuru Ralan	27268	10045.94	834.65	215.01	210.17	16.98	1276.81	127.69	1149.12	1.1583	0	27.6485937	28.81	27.88	1120.08	2.5071359	safe	0
12	Wokha	Bhandari	49715	22870.1	1900.13	798.84	478.47	46.21	3223.65	322.37	2901.28	1.96812	0	26.9992703	28.97	27.23	2872.08	0.99852479	safe	0
13	Wokha	Sanis	44379	18434.72	1531.62	291.36	385.67	22.87	2231.52	223.15	2008.37	2.02356	0	56.5898128	58.61	57.07	1949.28	2.91828697	safe	0
14	Wokha	Wokha	26904	10647.08	884.6	220.2	222.75	7.99	1335.54	133.55	1201.99	0.05544	0.29	53.2246259	53.57	53.68	1147.96	4.45677585	safe	0
15	Kohima	Chiephobozou	59656	12581	922.79	144.32	151.7	8.02	1226.83	122.68	1104.15	0	0	35.974623	35.97	38.07	1066.08	3.25770955	safe	0
16	Kohima	Jakhama	24600	4492.73	329.53	260.1	54.17	20.16	663.96	66.39	597.57	0	0.2	11.7425691	11.94	12.43	584.94	1.99809227	safe	0
17	Kohima	Kohima	25655	3706.42	271.86	1196.8	44.69	52.19	1565.54	156.56	1408.98	0	0	125.171479	125.17	132.47	1276.51	8.88373149	safe	0
18	Kohima	Tseminyu	36389	7483.42	548.9	237.01	90.24	21.17	897.32	89.73	807.59	0	0	39.4714297	39.48	41.77	765.81	4.88861923	safe	0
19	Longleng	Longleng	34503.56	7344.54	581.93	222.1	80.67	4.2	888.9	88.89	800.01	0	0	5.96230368	5.96	10.75	789.26	0.74499069	safe	0
20	Longleng	Tamlu	21696.44	5545.08	439.35	111.97	60.9	2.12	614.34	61.43	552.91	0	0	2.70579533	2.7	4.9	548.02	0.48832541	safe	0
21	Mon	Wakching	34450	13969.73	809.43	75.11	175.67	1.19	1061.4	106.14	955.26	0	0	10.2351232	10.23	10.25	945.02	1.07091263	safe	0
22	Mon	Tobu	31288	4699.61	272.3	26.72	59.1	0.51	358.63	35.86	322.77	0	0	4.83468929	4.84	4.84	317.92	1.49951978	safe	0
23	Mon	Chen	37708	12467.75	722.4	12.38	156.79	0.33	891.9	89.19	802.71	0	0	26.292612	26.29	26.34	776.37	3.27515541	safe	0
24	Mon	Mon	25278	10324.52	598.22	38.54	129.83	0.3	766.89	76.69	690.2	0	0	29.8386114	29.84	29.89	660.31	4.32338453	safe	0
25	Mon	Pomching	26015	9683.27	561.06	72	121.77	1.87	756.7	75.67	681.03	0	0	28.4340052	28.44	28.49	652.53	4.17602749	safe	0
26	Mon	Tizit	23861	10367.56	600.71	61.65	130.38	1.94	794.68	79.47	715.21	10.98846	0.34	40.1330978	51.46	40.21	663.67	7.19508955	safe	0
27	Phek	Meluri	97649.74	5285.34	251.98	174.89	76.58	0.2	503.65	50.37	453.28	0	0	14.0835663	14.08	14.4	438.88	3.10624779	safe	0
28	Phek	Sekruzu	18197.28	2006.28	95.65	196.33	29.07	1.15	322.2	32.22	289.98	0	0	4.50793969	4.51	4.61	285.37	1.55527967	safe	0

29	Phek	Pfutsero	30044.41	1889.11	90.06	236.63	27.37	3.45	357.51	35.75	321.76	0	0	9.54941128	9.55	9.76	312	2.96805072	safe	0
30	Phek	Kikruma	16620.55	1051.3	50.12	229.74	15.23	3.31	298.4	29.84	268.56	0	0	3.87287189	3.87	3.96	264.6	1.44101877	safe	0
31	Phek	Phek	40088.02	1076.97	51.34	304.34	15.6	8.22	379.5	37.95	341.55	0	0	5.31910764	5.32	5.44	336.11	1.55760504	safe	0
32	Peren	Jalukie	65871	34337.53	1804.53	1236.74	493.39	58.02	3592.68	359.27	3233.41	181.548	0	45.284021	226.83	45.8	3006.06	7.01519449	safe	0
33	Peren	Peren	47063	14102.3	741.12	248.17	202.63	1.19	1193.11	119.31	1073.8	0.5148	0	13.243482	13.75	13.39	1059.9	1.28049916	safe	0
34	Peren	Tening	52166	15398.61	809.24	210.23	221.26	3.79	1244.52	124.46	1120.06	0.9405	0	20.0498333	20.99	20.28	1098.84	1.87400675	safe	0
35	Mokokchung	Longchem	14100	5011.83	391.06	64.38	109.42	4.99	569.85	56.98	512.87	25.94592	0	7.32782123	33.28	7.42	479.5	6.48897381	safe	0
36	Mokokchung	Mangkolemba	44812	15099.67	1178.19	190.67	329.65	9.31	1707.82	170.79	1537.03	47.20716	0	18.29517	65.5	18.52	1471.31	4.26146529	safe	0
37	Mokokchung	Ongpangkong South	22954	7946.47	620.04	42	173.48	0.05	835.57	83.55	752.02	0	0	12.4131227	12.41	12.57	739.45	1.65022207	safe	0
38	Mokokchung	Ongpangkong North	24572	8336.23	650.46	283.2	181.99	2.05	1117.7	111.77	1005.93	0	0	14.7611401	14.76	14.94	990.99	1.46729892	safe	0
39	Mokokchung	Changtongya	42289	14301.82	1115.94	133.91	312.23	2.14	1564.22	156.42	1407.8	9.5832	0	10.6268816	20.2	10.76	1387.47	1.43486291	safe	0
40	Mokokchung	Kubulong	12773	4346.94	339.18	61.31	94.9	0.49	495.88	49.59	446.29	0	0	0.09629656	0.1	0.1	446.19	0.02240696	safe	0
41	Dimapur	Dhansiripar	21215	16602.22	5373.1	408.95	621.14	46.93	6450.12	645.02	5805.1	143.2539	0	89.2745415	232.52	94.89	5566.96	4.00544349	safe	0
42	Dimapur	Kuhoboto	6976	4004.75	1080.07	247.19	149.83	23.03	1500.12	150.02	1350.1	79.70688	0	40.8273003	120.52	43.4	1227.01	8.92674617	safe	0
43	Dimapur	Niuland	9344	5258.67	1418.25	198.25	196.74	12.3	1825.54	182.55	1642.99	21.81168	0	54.7649126	76.59	58.21	1562.95	4.66162302	safe	0
44	Dimapur	Medziphema	55165	37180.03	11389.89	555.15	1391.02	110.38	13446.44	672.32	12774.12	493.054128	2.38	623.4921	1118.93	662.72	11615.96	8.75935094	safe	0
45	Tuensang	Chare	8271	511.04	39.88	5.4	11.13	0.03	56.44	5.65	50.79	0	0	1.40060217	1.4	1.42	49.37	2.75644812	safe	0
46	Tuensang	Chessore	22679	955.34	74.55	468.96	20.81	0	564.32	56.43	507.89	0	0	7.77302762	7.77	7.87	500.02	1.52985883	safe	0
47	Tuensang	Longkhim	14989	613.67	47.89	136.8	13.37	0	198.06	19.81	178.25	0	0	4.06262303	4.06	4.11	174.14	2.27769986	safe	0
48	Tuensang	Noksen	28340	1238.06	96.61	222.93	26.97	0.05	346.56	34.65	311.91	0	0	5.56547222	5.56	5.64	306.28	1.78256548	safe	0
49	Tuensang	Sangsangnyu	35307	1483.26	115.74	316.64	32.31	0.11	464.8	46.48	418.32	0	0	9.68967994	9.69	9.81	408.51	2.31640849	safe	0
50	Tuensang	Shamator	33609	1282.28	100.06	92.44	27.93	0.04	220.47	22.05	198.42	0	0	3.84138105	3.84	3.89	194.53	1.93528878	safe	0
51	Tuensang	Thonoknyu	53298	2003.14	156.31	221.1	43.63	0	421.04	42.1	378.94	0	0	3.9888726	3.99	4.04	374.9	1.05293714	safe	0
52	Tuensang	Noklak	57107	2036.64	158.93	407.23	44.36	0.03	610.55	61.06	549.49	0	0	7.67107305	7.68	7.77	541.71	1.39765965	safe	0

Annexure VII (i)

MINUTES OF THE 1ST SITTING MEETING OF STATE LEVEL COMMITTEE(SLC) ON GROUND WATER RESOURCES ASSESSMENT OF NAGALAND FOR THE ASSESSMENT YEAR 2023-24 AS ON MARCH 2024 HELD ON 20th JUNE 2024 AT 12.00 HRS THROUGH HYBRID MODE.

The first sitting of State Level Committee (SLC) on Ground Water Resources Assessment of Nagaland as on March 2024 was convened on 20th June 2024 at 12.00 hrs through Virtual/Online platform. The meeting was chaired by Sri John Kevi, Commissioner & Secretary to the Govt. of Nagaland, Geology & Mining, & Chairman, SLC. The Chairman of the SLC welcomed all representative members of the SLC-2024, Nagaland who have attended in the meeting.

The list of Members who attended the meeting is enclosed as Annexure I.

During his opening remarks, Chairman of the SLC highlighted about the importance of ground water. He informed that extraction of groundwater in Nagaland is practically negligible in all the districts except Dimapur. Rainfall is abundant in the state but there is acute shortage of water during the summer as majority of the rain is lost as surface run-off. Extraction of groundwater resources will help in the overall sustainable development of the State and its people and bring about agricultural revolution in this tribal state.

Sri Tapan Chakraborty, Regional Director & Member Secretary, of SLC welcomed all the representative members of the SLC-2024, Nagaland who have attended in the meeting. He informed that Ground Water Resources of Nagaland has been carried out jointly by Central Ground Water Board, NER, Guwahati, and Directorate of Geology & Mining, Nagaland (State Nodal Department) in coordination with other members/departments of SLC. He highlighted that all the assessment units of Nagaland as per GWRA 2023 are in safe category as well as future allocation of ground water is also sufficient. So, State Government can judiciously develop the ground water resource mainly for agricultural use, however, at no point of time the extraction level should exceed 70%.

Regional Director, CGWB has also informed that after completion of the assessment exercise for 2024, the final report with its technical data will help in understanding of the present ground water scenario in Nagaland and prove valuable to policy makers, technical experts, professionals, and user agencies for management of ground water development in the state in planned manner.

With due permission of the Chair, Dr. S S Singh, Scientist-D (HG) & OIC of GWRA CGWB, NER, Guwahati gave a detail key point on agenda items like consideration of block as an assessment unit, Timeline of assessment, INGRES software, data requirement for calculating Dynamic Ground Water Resource as on 2024. He pointed out that for more accuracy of estimation of ground water resource of the state, the concerned departments should provide all the required data.

With due permission of the Chair, Ms Anenuo Pienyu, Scientist-C, and Dr. S S Singh, Scientist-D gave a detail power point presentation on agenda items. A detailed discussion on Dynamic GWRE was done where various queries were addressed. The assessment of Dynamic Ground Water Resources of Nagaland as on March 2024 is to be completed by September 2024 as per the timeline of GWRE-2024. Committee members discussed in detail on the methodology GEC 2015 and constraints of non-availability of various field data etc.

After thorough discussion all the members of SLC agreed and accepted that

i. The existing 52 nos. of assessment units in 11 districts used in the GWRA 2023 will remain the same in the GWRA of 2024.

ii. Firming up of assessment units as per latest data (administrative boundary of districts/blocks) and providing "shape file" of the same will remain same

iii. Collection and sharing of data for GWRA 2024 by respective SLC members and would be submitted to the Chairman & Member Secretary, SLC (Nagaland)

iv. Initiation of the manual and Software based INGRES assessment with the available data and completion of the assessment by September 2024 as per the Timeline provided by CLEC

v. All the concerned state government departments should provide all the requisite data to CGWB and DGM, Nagaland(State Nodal Department) as per the required format within 15th July 2024. The required data format will be prepared by CGWB and share it to all the concerned Head of Departments.

vi. The details of block wise / district wise Spring data of JJM (geo-coordinates, type of spring, pre-monsoon & post-monsoon discharge etc.) is to be provided by PHED, Nagaland

vii. Domestic ground water extraction data to be provided by PHED, Nagaland

viii. All the detail surface and ground water irrigation data, Crop water requirement is to be provided by Irrigation & Water Resources Department, Nagaland

ix. Use of data on PMKSY-HKKP-GW schemes implemented by WRD in the GWRA 2024 of Nagaland

x. Data of water conservation structures, tanks, and ponds to be provided by Soil & Water Conservation, Nagaland

xi. Creation of District level cell and deployment of district level Nodal officers of GWRA-2024, Nagaland for smooth functioning of the SLC

xii. Chairman, SLC proposed to arranged the next SLC meeting in physical mode. He has also urged to SLC members to attend the time-to-time workshop and training programmes on IN-GRES, data management etc. that are to be organised by IIT, Hyderabad for better interaction about the software & assessment

The meeting ended with a Vote of thanks by Sri Newmai Asingbow, Joint Director & Nodal Officer GW & GWRA-Nagaland, Directorate of Geology & Mining, Nagaland, Dimapur

Sri Tapan Chakraborty
Regional Director,CGWB, NER
Member Secretary, SLC

Sri John Kevi Angami
Commr. & Secy
to the Govt. of Nagaland,
& Chairman, SLC

ANNEXURE I

LIST OF MEMBERS ATTENDED

1. Sri John Kevi, Commissioner & Secretary to Govt. of Nagaland, Geology & Mining & Chairman of SLC , Nagaland
2. Sri Tapan Chakraborty, Regional Director, Central Ground Water Board, NER & Member Secretary, SLC, Nagaland
3. Dr. S S Singh, Scientist-D(HG) & OIC, GWRA, Central Ground Water Board, NER, Guwahati
4. Smt.Amentoli Anar, Deputy Secretary, PHED, Public Health Engineering Department, Nagaland, New Capital Complex, Kohima,797004
5. Sri Newmai Asingbow, Joint Director & Nodal Officer GW & GWRA-Nagaland, Directorate of Geology & Mining, Nagaland, Dimapur
6. Representative of Urban Development Department, Govt. of Nagaland, Kohima
7. Representatives of Soil & Water Conservation, Govt. of Nagaland, Kohima
8. Er. Khrotso Koza, Executive Engineer, Water Resource Department, Nagaland, New Capital Complex, Kohima,797004
9. Ms Chonchibeni Ezung, Hydrogeologist, WSSO, PHED, Public Health Engineering Department, Nagaland, New Capital Complex, Kohima,797004
10. Ms Wonjano Mozhui, Scientist-D, Central Ground Water Board, NER, Guwahati
11. Ms Zumchilo Ezung, Scientist-C, Central Ground Water Board, NER, Guwahati
12. Ms Anenuo Pienyu, Scientist-C, Central Ground Water Board, SUO, Shillong
13. Myngthungo Jami, Geologist, Directorate of Geology & Mining, Nagaland, Dimapur
14. Daventhung, Asst. Geologist, Directorate of Geology & Mining, Nagaland, Dimapur

Annexure VII (ii)

MINUTES OF THE STATE LEVEL COMMITTEE MEETING OF GROUND WATER RESOURCES ESTIMATION, 2024 FOR THE STATE OF NAGALAND ON 12th SEPTEMBER 2024

The meeting of the State Level Committee for Ground Water Resources Assessment of Nagaland, 2024 was held on 12th September (Thursday) 2024 at 12.00 Noon in the office Chamber of the Commissioner and Secretary, Geology and Mining Department, Nagaland Civil Secretariat, Kohima under the Chairmanship of Shri, John Kevi Angami, Commissioner and Secretary, Geology and Mining Department, Government of Nagaland.

The meeting was chaired by Shri. John Kevi Angami, Commissioner and Secretary, Geology and Mining, Govt. of Nagaland. At the outset the chairman of the SLC welcomed all the members present in the meeting.

With due permission from the chair, Shri. V. Kezo, Scientist D, Central Ground Water Board, NER, Guwahati on behalf of the Regional Director & Member Secretary SLC, CGWB, NER, Guwahati welcomed the members of the committee. He informed that the Ground Water Resources Assessment of Nagaland 2024 has been done jointly by Central Ground Water Board, NER Guwahati and Department of Geology and Mining, Nagaland in co-ordination with other departments of the State Level Committee. He highlighted that the Ground Water Resources Assessment unit has been carried out for 52 nos of blocks as per 2011 census of India.

Ms. Anenuo Pienyu, Scientist-C, CGWB, NER gave a detailed presentation on Ground Water Resources Estimation,2024 for the state of Nagaland. She informed the members that the computation of dynamic ground water resources of Nagaland was done through IN-GRES software. The IN-GRES is a software/web-based application developed by CGWB in collaboration with Vassar Lab, IIT- Hyderabad. She explained the methodology of Ground Water Resource Estimation along with findings.

With due permission from the chair, the committee members discussed in detail about the calculation and methodology of Ground Water Estimation, 2024. The committee also felt the need to include more line departments such as Agriculture Department, Land Resource Department, Fisheries Department, Rural Development Department and Industries Department so that more field data may be utilised for resources calculation. The committee also discussed about the need for assessment of ground water as per the blocks of all 16 districts of Nagaland seperately.

The Chairman of the State Level Committee appreciated and congratulated the effort taken by CGWB, NER, Guwahati and to all the department of SLC for providing and computing the data as per scheduled.

After a thorough discussion, all the members of the State Level Committee for Ground Water Resources Assessment of Nagaland, 2024 accepted and approved upon the computations of the Dynamic Ground Water Resource Assessment of Nagaland,2024.

The meeting ended with vote of thanks by Myinthungo Jami, Senior Geologist, Geology and Mining Department, Government of Nagaland.

Attendance list is enclosed in Annexure I.

(John Kevi Angami)
Commissioner and Secretary, Geology and Mining, Govt. Of Nagaland
&
Chairman,
State Level Committee (SLC) for Ground Water Resources Estimation of Nagaland

MEETING OF STATE LEVEL COMMITTEE (SLC) ON DYNAMIC GROUND WATER RESOURCE ASSESSMENT OF NAGALAND AS ON MARCH 2024

Dated 12th Septemeber 2024

Venue : Office Chamber of Commissioner & Secretary, Geology & Mining Department, Nagaland Civil Secretariat, Kohima

S.No.	Name	Organisation	Ph.No.	Email Id	Signature
1.	John Kevi Angami	Commissioner&Secretary, DGM Nagaland	9436275764	JohnJokev@gmail.com	
2.	Rontilo Keil	Soil & Water Conservation	8787881842	Rontilo@outlook.com	12/07/2024
3.	Er. Sobu Angami	Water Resources Deptt.	9436001042	erssobu@gmail.com	12/09/24
4.	Myinthungo Jami	G & Mining	7005585872	myin87@gmail.com	12/7/24
5.	Er. VETHIZO NYEKHA	Soil & water conservation	8119841918	nyekha vethizo@gmail.com	12/9/24
6.	Amenuo Pienyu	Scientist-C, CGWB	9089447789	a.pienyu@assam.gov.in	
7.	V. Kezo	Sc-D	94360113 54	[illegible]	
8.	Dr. O. Chubalemla Ezung	Hydrogeologist, PHED	7630974038	ezungc@yahoo.com	
9.	Vikenuolie	PHED	9436012280	vike.[illegible]@gmail.com	
10.					

ABBREVIATIONS

CGWA	Central Ground Water Authority
CGWB	Central Ground Water Board
bcm	Billion cubic metre
CLEG	Central Level Expert Group for overall reassessment of ground water resource of the country
GEC-1997	Ground Water Resources Estimation Committee, 1997
GEC-2015	Ground Water Resources Estimation Committee, 2015
GWRA	Ground Water Resources Assessment
ham	Hectare metre
IMD	India Meteorological Department
lps	Litres per second
m	Meter
m bgl	Meter below ground level
mcm	Million cubic metre
M.I.	Minor Irrigation
DOWR, RD & GR	Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti, Govt. of India
NAQUIM	National Aquifer Mapping & Management Programme
SLC	State Level Committee

CONTRIBUTORS

The computation of Dynamic Ground water Resources of Nagaland for the Assessment Year 2023-24 has been carried out jointly by Central Ground Water Board, North Eastern Region and Directorate of Geology and Mining, Government of Nagaland (State Nodal Department of GWRA), as per the Ground Water Estimation Committee-2015 (GEC-2015) methodology under the guidance of the State Level Committee (SLC) and overall supervision of Central Level Expert Group (CLEG). Field data generated by CGWB and statistical information/data generated/compiled by Nagaland State Departments such as Dept. of Water Resources, Directorate of Economic & Statistics, Public Health & Engineering Dept., Dept. of Commerce and Industries, Dept. of Agriculture, Dept. of Soil and water Conservation, Department of Urban affairs, Directorate of Geology and Mining etc and Central Govt. organization such as IMD, CWC, Brahmaputra Board, NIH etc were used in assessing the ground water resources of the State. The assessment and compilation of the report was carried under the guidance of John Kevi Angami, Commissioner and Secretary, Geology and Mining, Govt. of Nagaland and Chairman, State Level Committee and Tapan Chakraborty, Regional Director, CGWB, NER, Guwahati.

Principal Contributors:

1. Vekhosa Kezo, Scientist-D, CGWB, NER, Guwahati
2. Anenuo Pienyu, Scientist-C, CGWB, SUO, Shillong

Contributors:

1. Shri. Khikiya Rengma, Director, Geology and Mining, Government of Nagaland (State Nodal Dept.)
2. All Members/Departments of SLC on GWRA, Nagaland, 2024
3. Dr. D J Khound, Scientist-D, CGWB, NER, Guwahati
4. Wonjano Mozhui, Scientist-D, CGWB, NER, Guwahati
5. Mophi Mili, Scientist-C, CGWB, NER, Guwahati
6. Zumchilo T. Ezung, Scientist-C, CGWB, NER, Guwahati
7. Tiamenba Longshir, AHG, CGWB, NER, Guwahati

Team CGWB Central Headquarters:

1. S. N. Dwivedi, Scientist-D & Director (Admin), Central Ground Water Board, CHQ, Faridabad
2. Sujatro Ray Chowdhuri, Scientist-C, Central Ground Water Board, CHQ, Faridabad.
3. Subhra Satapathy, Scientist-C, Central Ground Water Board, CHQ, Faridabad

Team INGRES:

1. Dr. KBVN Phanindra, Professor, IIT Hyderabad
2. M. Prem Chand, Research Scholar, IIT Hyderabad

Overall Guidance & Supervision:

1. Dr. Sunil Kumar Ambast, Chairman, Central Ground Water Board, CHQ, Faridabad.
2. T. S. Anitha Shyam, Member South, Central Ground Water Board, CHQ, Faridabad.
3. N. Varadaraj, Member East, Central Ground Water Board, CHQ, Faridabad.
4. John Kevi Angami, Commissioner and Secretary, Geology and Mining, Govt. of Nagaland
5. Tapan Chakraborty, Regional Director, CGWB, NER, Guwahati
6. Biplab Ray, Scientist-D & TS, CGWB, NER, Guwahati
7. Dr. S S Singh, Scientist-D & OIC, GWRA 2024, NER, Guwahati