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GROUNDWATER RESOURCES OF UNION TERRITORY OF LADAKH (As on 31-03-2020)

Prepared Jointly
By

DEPARTMENT OF JAL SHAKTI, UT OF LADAKH

CENTRAL GROUNDWATER BOARD
NORTH WESTERN HIMALAYAN REGION
JAMMU

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सत्यमेव जयते

Commissioner/Secretary
PHE/I&FC Department
Union Territory of Ladakh

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FOREWORD

In a time of growing water crisis, accurate data and knowledge of existing water reservoirs, whether surface or underground, becomes extremely important for its judicious use and development planning.

The report on Ground Water Resources Estimation as on 31st March 2020, of Union Territory of Ladakh has been prepared by the joint efforts of Central Ground Water Board North Western Himalayan Region, Jammu and PHE/IFC Department, UT Administration of Ladakh. The report prepared on guidelines by the Ground Water Resource Estimation Committee (GEC 2015), Government of India, gives details on Total Annual Replenishable Ground Water Resources, its present draft and scope for future development.

The overall stage of ground water development in Union Territory of Ladakh is estimated to 17.90% (as on 31st March, 2020). In Leh district, the stage of ground water development is 36.13% and in Kargil district it is mere 3.40%. Since most of area of Union Territory of Ladakh has highly rugged and hilly topography, each district has been considered as an assessment unit instead of block as an assessment unit. The report gives good news by concluding that both assessment units (districts) are in the “Safe” category. The Union Territory of Ladakh can plan further developmental activities by drawing up to 70% of the underground water resources and can remain in the safe category.

However, being in safe category, need of water harvesting, promoting water efficient agricultural practices and conserving water during winters do not become less important in any manner. Since the hilly and areas with high slopes have not been considered for Ground Water Resources Estimation, these areas still remain major challenge for scientists, engineers and planners for providing safe and sustainable water supply to the residents as well as other utilities.

I would like to appreciate the efforts of each person associated with data collection, analysis and preparation of this report by officers of Central Ground Water Board, Jammu and PHE/IFC Department of UT of Ladakh.

I personally feel that this report will be of immense use to the administrators, planners and agencies engaged in the development and regulation of ground water resources.

Ajeet Kumar Sahu

PREFACE

For an efficient management and development of ground water resources, it is imperative to have a reliable estimation of Ground Water Resources. Estimation of ground water resources for all watersheds or administrative units was recommended in Ground Water Estimation Committee (GEC-2015) is also applicable for the Union Territory of Ladakh. Union Territory being hilly terrain, whole of the area has not been assessed. The ground water resources have been estimated as on 31st of March 2020, for plains and valleys of Union Territory having surface slope of less than 20%.

As per the estimation, both the assessment units (two districts) of Union Territory of Ladakh fall under the safe category and overall stage of ground water development in Union Territory is 19.76%. The stage of ground water development is 3.98% in Kargil District and 36.13% in Leh District.

The efforts made by the Ground Water Assessment Cell, comprising of officers from Central Ground Water Board, North Western Himalayan Region, Jammu and Department of Jal Shakti, Union Territory of Ladakh, in bringing out this report are highly appreciated. Working on Ingres platform, S/Sh. B Abhishek, Scientist-B, and Rayees Pir Ahmad, Assistant Hydrogeologist completed the assignment well in time, under the supervision of Sh. Vidya Nand Negi Scientist-D and their efforts are worth mention.

The present report consists of information on annually replenishable ground water resources and Static/ In-storage ground water resources. The details of natural losses, available ground water resources, ground water draft, allocation for domestic and industrial uses, available ground water resources for future irrigation and the stage of ground water development have also been provided.

This report is a repository of very useful data for all planners and user agencies engaged in development and management of groundwater resources in the Union Territory of Ladakh with hope that it would be utilized fully for real time management of ground water resources.

(Mohinder Lal Angurala)
Head of Office

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CHAPTER-1
INTRODUCTION

1.1 BACKGROUND

Groundwater is an important source to meet the water requirements of various sectors like irrigation, domestic, and industries. Groundwater usage, if left unregulated, may lead to serious inter-sectoral conflicts. Hence the growth in both agriculture and industry is impingent on how India can manage its groundwater resources, particularly the aquifers in different parts of the country. The sustainable development of groundwater resources requires a precise quantitative assessment based on reasonably valid scientific principles. The fundamental basis for good groundwater management is a clear understanding of aquifers and the status of groundwater accumulation and movement in these aquifers.

To assess the irrigation potential from the groundwater, an estimate of groundwater resources was made in the year 1973 by the Ministry of Agriculture in consultation with Union Territory groundwater and minor irrigation organization. Subsequently, in the early eighties, the groundwater resource was re-estimated based on the Methodology proposed by the Groundwater Over Exploitation Committee-1977. In 1982, the Government of India had constituted a Groundwater Estimation Committee to improve the quantitative assessment of groundwater and to suggest a methodology after considering all aspects of groundwater estimation. This Committee recommended a methodology, namely: Groundwater Estimation Committee Methodology–1984 (GEC-84). Since then, the Central Groundwater Board and State Groundwater Organization have adopted this GEC–1984 methodology and estimated the groundwater resource in the Jammu and Kashmir Union Territory.

However, some limitations were encountered in the estimation, and this necessitated revision of methodology for more accurate assessment. Therefore, to review GEC– 84 and to look into all the related issues, a Committee on Groundwater Estimation was constituted vide GOI, MOWR Notification No. 3/9/93-GWII/2333 dated 13.11.1995, which had recommended a revised methodology, namely: Groundwater Resource Estimation Methodology–1997 (GEC-97) for estimating the groundwater resource for all the States in future. The Government of India also desired that a Working Group on the Estimation of Groundwater Resource and Irrigation potential from Groundwater should be constituted in each State for furnishing the relevant information to the Planning Commission and to review the GEC-97 and to suggest suitable modification if any. However, the R&D Advisory Committee on Groundwater Estimation, Government of India, thought of refining the existing Methodology, i.e., GEC-1997, and strengthening the norms for various parameters for resource estimation like specific yield, canal seepage factor, rainfall recharge factor, irrigation return flow factor, etc. Therefore, it was decided in the 11th Meeting of the R and D Advisory Committee on Groundwater Estimation, held on 13.11.2009, to carry out the Groundwater Estimation in the alluvial areas as per the norms mentioned in the Methodology GEC-1997 with the refinement of data.

The Groundwater Estimation Committee- 1997 has been the basis of groundwater assessment in the country for the last two decades. The groundwater development program implemented in the country was also guided by groundwater resource availability worked out using this methodology. The experience gained in the last more than one decade of employing this methodology supplemented by several research and pilot project studies has brought to focus the need to update this methodology of groundwater resource assessment. The National Water Policy also enunciates periodic assessment of groundwater potential on a scientific basis.

In 2010, the Ministry of Water Resources constituted a Central Level Expert Group (CLEG) for overall supervision of the reassessment of groundwater resources in the entire country. The group finalized its report, and the draft report was circulated to all the members of the Committee for their views. During the fourth meeting of the committee, held on 03-12-2015, the draft report of

“Groundwater Resource Estimation Committee - 2015 (GEC 2015) was discussed in detail. The views expressed by the members for revised methodology were considered, and necessary modifications were made and the report of the Committee was finalized. As decided in the meeting held on 09.02.2016 at New Delhi on Revision of Groundwater estimation Methodology-97, a workshop on “Groundwater Resource Estimation Methodology - 2015” was held on 24th January 2017 at CWPRS, Khadakwasla, Pune involving stakeholders and experts. The major changes proposed in the workshop were (i) to change the criteria for categorization of assessment units and (ii) to remove the potentiality tag.

The revised methodology, as recommended, has incorporated several changes compared to the recommendations of the Groundwater Estimation Committee - 1997. The revised methodology GEC 2015 recommends aquifer-wise groundwater resource assessment to which demarcation of lateral as well as vertical extent and disposition of different aquifers is pre-requisite. However, it is recommended that groundwater resources may be assessed to a depth of 100m in hard rock areas and 300m in soft rock areas till the aquifer geometry is completely established throughout the country through aquifer mapping.

It also recommends the estimation of Replenishable and in-storage groundwater resources for both unconfined and confined aquifers. Keeping in view of the rapid change in groundwater extraction, GEC-2015 recommends resource estimation once every three years. This methodology recommends that after the assessment is done, a quality flag may be added to the assessment unit for parameters salinity, fluoride, and arsenic. In inhabited hilly areas, where surface and sub-surface runoff are high and generally water level data is missing, it is difficult to compute the various components of the water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for ‘groundwater resources’ in hilly areas.

The Ministry of Jal Shakti Department of Water Resources RD&GR requested all the State/UT Governments to constitute State/UT Level Committees for overall supervision of assessment of groundwater resources at the state level. As per guidelines of Central Groundwater Board, Ladakh Government, vide Government Order No. 11-LA(GAD) of 2020 Dated: 07-12-2020 (Appendix–1), has notified a committee, namely: “UT Level Committee on Groundwater Resource Estimation” as of March 2020 for proper monitoring and Finalization of the Report. Also, minutes of the meeting held with Secretary PHE, I & FC Ladakh Sh Ashok Sahoo in his camber on 16-12-2020 and 10-03-2021 is attached (Appendix–2 and 3); Govt. of Ladakh constituted a “Nodal Officer” – Chief Engineer I&FC for Groundwater Resource Estimation as a standing forum for finalization of Groundwater Assessment Report before putting up to State Level Committee.

Accordingly, steps were taken to carry out the groundwater resource assessment with data for the period 2019-2020 for the present study. The recommendations of GEC-2015 have been suitably incorporated in the present report.

1.2 HISTORICAL BACKGROUND

Ladakh ("land of high passes") is a region in northern India. It is located between the Kunlun mountain range in the north and the main Himalayas to the south. Ladakh is well-known for its remote mountain scenery. It is inhabited by a mix of Indo-Aryan and Tibetan people. Their language is an archaic dialect of the Tibetan language. Historically, the region of Ladakh included Baltistan, the Indus and Zanskar Valleys, Lahaul and Spiti, Aksai Chin, and the Nubra Valley. The modern region borders Tibet to the east, Lahaul and Spiti to the south, and Kashmir, Jammu, and Baltistan to the west. In the past, Ladakh was important for trade. It was where several important trade routes met. However, China closed the border with Tibet in the

1960s, and since then, international trade has suffered. Tourism is an exception, and it has been very important for Ladakh's economy since about 1974.

The largest town in Ladakh is Leh. Leh is followed by Kargil as the second largest town in Ladakh. Under Jammu and Kashmir Reorganization Act, 2019, Ladakh was declared as a separate union territory. In August 2019, a reorganization act was passed by the Parliament of India , which contained provisions to reconstitute Ladakh as a union territory, separate from the rest of Jammu and Kashmir, on 31 October 2019. Under the terms of the act, the union territory is administered by a Lieutenant Governor acting on behalf of the Central Government of India. Ladakh is the highest plateau in the Indian states; much of it is over 3,000 m above sea level.

It spans the Himalayan and Karakoram mountain ranges and the upper Indus River valley. The Indus is the most important part of Ladakh for its people. Most major historical and current towns (Shey, Leh, Basgo, and Tingmosgang) are located close to the Indus River. The stretch of the Indus flowing through Ladakh is the only part of this river in India. The river is sacred in Hindu religion and culture. Ladakh Range, which is a southeastern extension of the Karakoram Range, and the upper Indus River valley is one of the highest regions of the world. Its natural features consist mainly of high plains and deep valleys. The high plain predominates in the east, diminishing gradually toward the west. In southeastern Ladakh lies Rupshu, an area of large, brackish lakes with a uniform elevation of about 4,100 meters. To the northwest of Rupshu lies the Zaskar Range, an inaccessible region where the people and the cattle remain indoors for much of the year because of the cold. Zaskar is drained by the Zaskar River, which, flowing northward, joins the Indus River below Leh. In the heart of Ladakh, farther to the north, cultivation through manuring and irrigation is practiced by farmers living in valley villages at elevations between about (2,750 and 4,550 meters). **Kargil**, a portion of the western Ladakh union territory, northwestern India. Centered on the town of Kargil lies in the Zaskar Range of the Himalayas and abuts the line of control between India and Pakistan. Kargil town, located roughly equidistant between Srinagar (southwest) and Leh (southeast), is considered the gateway to Ladakh.

Kargil’s landscape is mountainous, rugged, and high, the minimum elevation being some 8,000 feet (2,440 meters). The climate is cold and dry, with scanty precipitation that falls mainly as snow in winter. One locality, Drass, is reputed to be one of the world’s coldest permanently inhabited places, with winter temperatures dropping to as low as −40 °F (−40 °C) or colder. Vegetation is extremely sparse in Ladakh except along streambeds and wetlands on high slopes. The plant *Ladakiella klimesii*, growing up to 6,150 meters above sea level, was first described here and named after this region. The first European to study the wildlife of this region was William Moorcroft in 1820, followed by Ferdinand Stoliczka, an Austrian-Czech paleontologist, who carried out a massive expedition there in the 1870s.

1.3 ASSESSMENT AREA

The Union Territory of Ladakh is the northern most Union territory of India. It lies between the latitudes 32º17’ to 36º58’ N and longitudes 73º26’ to 80º30’ E. The UT has a total geographical area of 59,146 Sq. Km. The Union Territory has an international border with Pakistan in the west. The States of Himachal Pradesh forms its southern border, and the UT of Jammu & Kashmir form the Southern and southwestern border. Major parts of the UT represent high and rugged mountainous terrain.

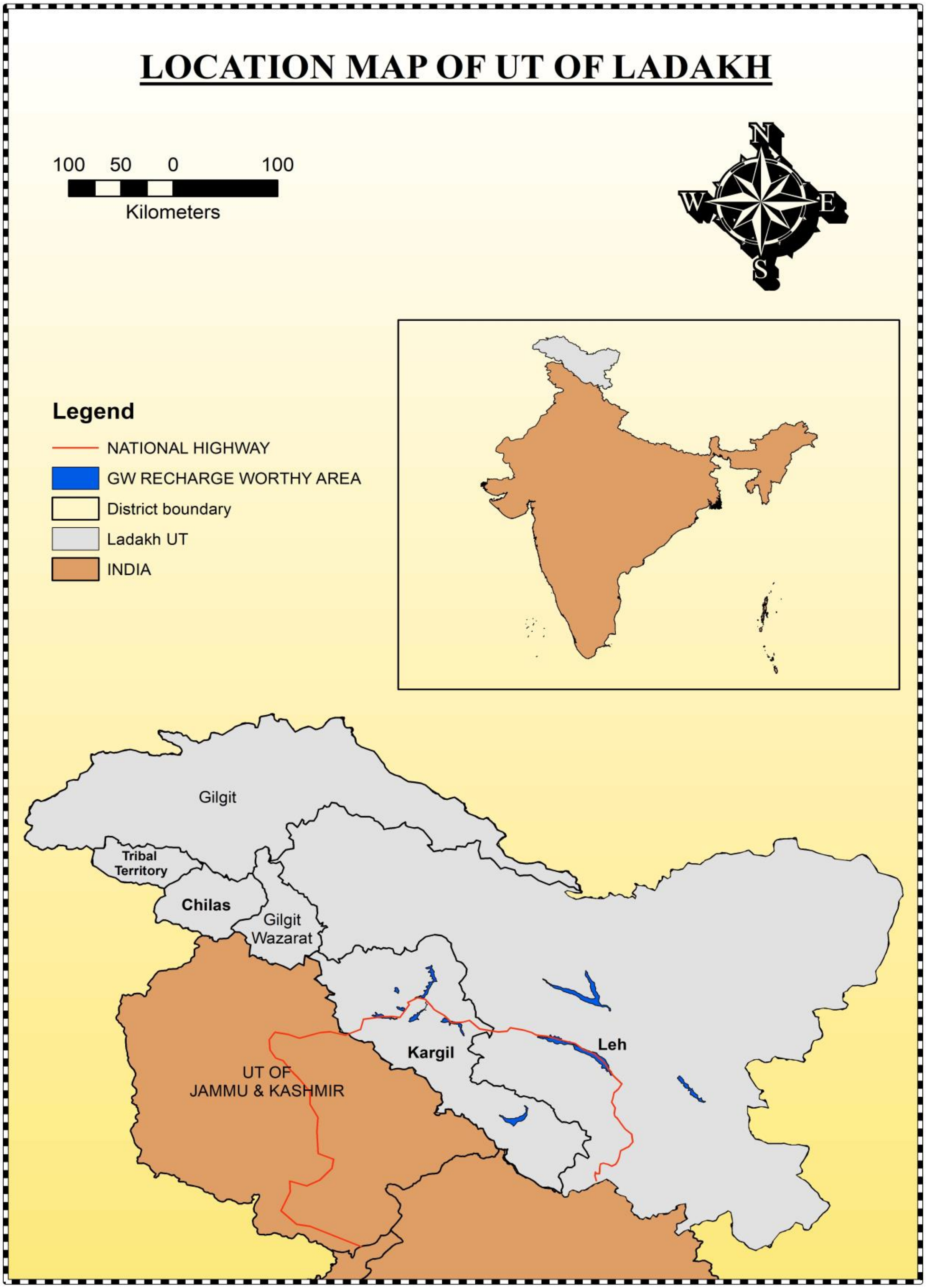


Figure 1 Location map of UT of Ladakh

The UT of Ladakh is located in the northernmost part of India, connected with the rest of the parts of the country by road through NH – 44 and Himachal Pradesh via Manali. Administratively the UT of Ladakh is divided into 02 districts, namely Leh and Kargil district. The administrative map of the UT is presented in Fig 1. The remaining four administrative units are inaccessible and under illegal occupation of Pakistan (Pok)

The UT of Ladakh has great diversity in its temperature and precipitation. The climate over the greater parts of the state resembles the mountainous and continental parts of the temperate latitudes. Unlike other States, groundwater resources estimation cannot be done block-wise since the entire Union Territory is hilly and mountainous. Therefore, instead of a block as a unit for the evaluation of the groundwater resources is taken as valleys and plain areas of all districts.

1.4 PHYSIOGRAPHY

The Topography of the region is extremely rugged, mountainous, and highly inaccessible. The highest passes like Khardungla (The highest motorable road in the world) and the largest glaciers like Siachen (the world's highest battlefield) are located in this district. The altitude of the area varies from 3000-8000 m amsl. Indus and Shyok are the main valleys. Indus River is the lifeline of the entire Leh district. The important plains are the Leh plain, More plain, Hanle Plain, Depsang plain, and soda plain. Some of the highest peaks of the Western Himalayas are also located in this region.

GREAT HIMALAYA / HIGHER HIMALAYA

The Great Himalayas, with mighty snowy peaks, average height exceeding 6000 m, is higher, steeper, and more rugged than Lesser Himalayan Zone. Nanga Parbat attaining an elevation of 8126 m is located in this part of the Himalayas. The twin peak of Nun (7135 m) and Kun (7077 m) is also located in this part of the Great Himalaya. Rising steeply like a wall from Lesser Himalaya, the whole of this zone with the exception of the deep ravines lies above the perpetual snow line. The mountain ranges in this zone too have steep southern slopes and gentler northern slopes. Further, the mountain ranges are intersected by high glaciated valleys in the upper part and dissected by streams into transverse gorges in the lower part. About 140 km long and 40 km wide, the Kashmir Valley is enclosed from the west and south by Pir Panjal, whereas to the northeast by Great Himalaya. It abounds in many beautiful and picturesque flower valleys, meadows, lakes, rivers, and man-made gardens. Jhelum River, along with its tributaries, form the principal drainage of the Valley. It is a structural Basin covering an area of about 4865 sq km representing an old lacustrine bed. The Valley shows temperate summers and severe winters in which the night temperature falls below freezing point.

TRANS-HIMALAYAN ZONE

The Ladakh region to the north and east of Kashmir Valley is known for its high-altitude terrain and extremely rigorous climate. This zone is also characterized by WNW-ESE to NW-SE trending mountain ranges. Zanskar, Ladakh, and Karakoram ranges are located in this zone. Ladakh Range, situated between Indus and Shyok rivers, attains height, up to 6529 m in the central part. The glaciers and streams draining its flanks have incised deep valleys filled with moraines.

Indus Valley, located between Zanskar Range in the south and Ladakh Range in the north, is a broad, flat Valley with its Valley floor elevation varying from 3195 m at Leh to 3395 m at Upshi. Bajada (Piedmont fan surface), erosional and depositional terraces, recent flood plains with associated bars of Indus River, palaeolake, and aeolian surfaces are the main geomorphic features of Indus Valley. Shyok Valley occupies the terrain between Ladakh and Karakoram ranges. It is also a broad open Valley characterized by relatively dense vegetation. Karakoram Range, with K2 (8610 m), the world's second-highest peak occurring north of Ladakh Range, has its entire crest-line covered with perpetual snow with several giant glaciers crawling slowly down its prominent slope, glaciers like Siachen occur along the southern face of the range. To the immediate north of the Great Himalaya in the Zanskar Range bounded by Indus and Tsarap Chu-Doda rivers to the north and south, respectively

1.4.1 DRAINAGE

As already stated, the main river in this region is the Indus River, which originates from Mt. Kailash in Tibet and flows towards the NW direction. Indus basin has two sub-basins, namely Shyok and Gilgit Qara–Qash river basin. Two main rivers falling in this are Nubra and Shyok rivers. Nubra is a perennial river and is originated from Siachen Glacier and flows in Northwest to southeast direction. Syok River is also a perennial river and is originated from South Rimo Glacier and Central Rimo Glacier.

The important major rivers draining the Kargil area are Dras, Suru, Zanskar

1.4.2 SOILS

The soil of this region is sandy to loamy and deficient in organic matter, and the availability of phosphorus and potashes low and mixed with stones and gravels. It is shallow in formation, weakly friable, and being sandy, it is vulnerable to all types of erosion. As a result, soils developed on river terraces highly porous and coarse-grained. The fertility of the soil varies from place to place, and the growing season is very short.

1.4.3 CLIMATE

Ladakh experiences a cold continental arid climate, typical of the Tibetan plateau in the northeast comprising the Ladakh region. The entire Ladakh region lies in the rain shadow region of the Himalayas. The climate is classified as cold continental climate, the temperature being as low as –35ºC to –45ºc during the night in winter and remains sub-zero during the day.

The area falls in the rain shadow region of the Himalayas, and as such, precipitation is significantly less and scanty. The annual precipitation in the form of rainfall is 80-120 mm per year, whereas snowfall is about 140 mm/year.

1.4.4 GEOLOGY

Geologically the area is the collision ground of two continental masses, the Indian plate in the south and the Tibetan plate in the north bringing in the juxtaposition of dissimilar rock assembly; ages with volcanic ultrabasic rocks. The geological formations right from Pre-Cambrian to Recent are present in the Area.

Table 1 Geology of Ladakh UT.

Formation	Age
Alluvial Lacustrine deposits, fluvioglacial outwash material, Lamayuru deposits, and Laminated Clays	Recent to Sub-Recent
Siwalik Clays/Teritiaries, liyan formation, Shegol formations (with Ophiolites)	Miocene to Pleistocene
Ninden/kalche formation	Eocene
Khalsa formation/shyok volcanic/Karakoram formation	Cretaceous
Qazilanker Conglomerate/zangla formation/Kiota limestones	Jurassic
Murgo formation	Triassic
Panjal Traps	Permian

Pengong Granitoids, Kuling formation, Phe volcanic/sasar Brangsa formation, Lipak formation	Permo-Carboniferous
Muth Qurtzites/tacke/Kelung formation	Silurian-Devonian
Thankung Schists/Phe formation, Pengong metasedimentary group	Cambro-Silurian
Karakoram Crystalline Complex/Lukung Schist, salkhalas, unclassified granites and gneisses	Pre-Cambrian

1.4.5 HYDROGEOLOGY

Based on geology and aquifer characteristics, the area of the Ladakh region can be divided into two broad hydrogeological units. These units are

I. Porous formations

II. Fissured formations.

I. Porous formations: -This includes moraines and Fluvioglacial Deposits of Ladakh. The area is situated on the northern bank of the Indus River and covers an area of about 100 sq. km between Ph18-01-21yang Nala in the west to Sabu Nala in the east. The sediments consist of morainic material, overlain by varved clays and silts of lacustrine origin, again overlain by morainic boulders and cobbles in mechanically disintegrated loose sandy matrix deposited by rivers.

II. *Fissured formations: -* These include hard igneous, sedimentary& metamorphic rocks.

1.5 LEH DISTRICT

This district has the distinction of having its border with three countries viz China in the north and east, Afganistan in the northwest corner, and Pakistan in the west. It is further bounded by Kargil district in the west and state of Himachal Pradesh towards South East. The total geographical area of the district is 81840 Sq.km. The altitude of the area varies from 3000-8000 m amsl. Indus and Shyok are the main valleys lndus river is the lifeline of the entire Leh district. The important plains are the Leh plain, More plain, Hanle Plain, Depsang plain, and soda plain. Some of the highest peaks of the Western Himalayas are also located in this district.

1.5.1 HYDROGEOLOGY AND SUB SURFACE CORRELATION

Leh valley is a broad U-shaped valley bounded by the Ladakh range in the North and Zanskar range in the south. The plain is underlain by morainic deposits consisting of boulders, cobbles, pebbles embedded in an arenaceous matrix, and the lake deposits comprising predominantly of clays, sandy clays, and silt. The sediments are overlain by varved clays and silts of lacustrine origin again succeeded by morainic boulders and cobbles in a disintegrated loose sandy matrix and alluvial deposits.

Groundwater Exploration by CGWB is confined to Leh Plains and Nubra Valley. A percussion rig was flown to this area in the year 1973, heralded a new chapter in Groundwater Exploration in India in view of the district's unique location. Seventeen exploratory wells, beginning from the year 1973, have been drilled in the district up to 1997.

Based on data collected from these boreholes as shown in table No. It is concluded that the depth to the water level in the constructed wells ranges from 1.30 m bgl at Zorawar fort to 43.36 m bgl at the ITBP II site. The Exploratory site at Trishul had to be abandoned, and the exploratory well at Project Himank yielded a meager discharge. Except for these two sites, the other eleven sites proved successful. The yield obtained from these wells ranged from as low as 197 lpm for 16.57 m drawdown at Skalzangling to as high as 1600 lpm for a drawdown of 3.0 m at Pituk site.

Groundwater exploration activities again resumed in the Leh district during the AAP 2005-2006. Eight exploratory tube wells and 01 Observation Well were constructed in Leh plains and

Nubra Valley. The Depth of tube wells ranges from 43 mts at Siachen to 84 mts at Patter Sahib and the yield varies from 1000 lpm at pather Sahib to 1200 lpm at Siachen Base-III.

Almost in all the boreholes, coarser Clastic sediments in the form of Sand, Cobbles, Pebbles, and boulders with very thin bands of finer Clastic sediments were encountered between 25 and 62.0 m. bgl. The Transmissivity values range between 204 to 28465 m^2/day.

No attempt has been made to draw Hydrogeological cross-sections in the absence of any major finer Clastic bands within the limited drilling depth of 65 to 70 m bgl. The electrical conductivity of groundwater remains within 360 micro-mhos-cm. Proving its suitability for every purpose.

1.6 KARGIL DISTRICT

Kargil district with headquarters at Kargil town lies between the northern latitude $75^0$45’ to $76^0$30’and longitude $34^0$15’ to $34^0$47’30”. Leh bounds this district on the northeastern side, **L**ine Of **C**ontrol in the north, and Anantnag, Baramula, Srinagar, and Doda districts on the South Western side. Suru, Zanskar, Drass Shamker Chikara, Wakna, Laws, and Indus were some of the valleys of this district. District Headquarters, Kargil, is approachable by National Highway NH-1A, from Srinagar, at a distance of 204 km. As the area is accessible by road from May to October and under the snow cover during the rest of the period.

Kargil district has a total geographical area of 14,036 sq km, comprising 129 villages (127 inhabitant villages and two un-inhabitant villages). Administratively, the district is divided into two tehsils (Kargil and Zanskar), 09 CD blocks (Kargil, Shaker, Drass, Sankoo, Zanskar, Shargole, Taisuru, G.M. Pur, and Cha development blocks), and 65 Village Panchayats.

1.6.1 HYDROGEOLOGY AND SUB SURFACE CORRELATION

Groundwater occurs mainly in the morainic deposits comprising of Talus and Scree formations. Groundwater levels in these deposits are very deep & range between 60 m to 75 m bgl
The chemical quality in the Kargil district is by and large fit for drinking and irrigation purposes. From the chemical quality point of view, groundwater in the area is fresh and potable with electrical conductivity (EC) generally less than 700 µS/cm at 25°C. But in Sankoo village, Fluoride content more than the permissible limits of 1.5 mg/lt is observed.
Central Groundwater Board has explored valley-fill deposits of Kumathang Cantt area by constructing one exploratory tubewell. The total depth of this tubewell is 86.00 m bgl. The zones encountered are 63.00 to 71.00 m and 78.00 to 84.00 m bgl.

CHAPTER 2
GROUNDWATER RESOURCES ESTIMATION METHODOLOGY

2.1 METHODOLOGY

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

2.2 PERIODICITY OF ASSESSMENT

Keeping in view of the rapid change in Groundwater Extraction, the committee recommends more frequent estimation of Groundwater Resources. The committee observes that the comprehensive assessment of Groundwater Resources is a time-intensive exercise. Hence as a tradeoff, it recommends that the resources should be assessed once in every three years. There is a considerable time lag between assessment and publication of the results as per the present practice. Hence the committee recommends making all-out efforts to reduce the time lag, and the results may be reported within the successive water year.

2.3 GROUNDWATER ASSESSMENT UNIT

This methodology recommends aquifer-wise groundwater resource assessment. An essential requirement for this is to demarcate lateral and vertical extent and disposition of different aquifers. A watershed with well-defined hydrological boundaries is an appropriate unit for groundwater resource estimation if the principal aquifer is other than alluvium. Groundwater resources worked out on watershed as a unit may be apportioned and presented on administrative units (block/ taluka/ mandal/ firka). This would facilitate local administration in the planning of groundwater management programs. Areas occupied by unconsolidated sediments (alluvial deposits, aeolian deposits, coastal deposits, etc.) usually have flat topography, and demarcation of watershed boundaries may not be possible in such areas. Until Aquifer Geometry is established on an appropriate scale, the existing practice of using watershed in hard rock areas and District/ mandals/ firkas in soft rock areas may be continued.

2.4 GROUNDWATER ASSESSMENT SUB-UNITS

It is recommended that groundwater recharge may be estimated for the entire assessment unit. Out of the total geographical area of the unit, hilly areas wherever slope is greater than 20%, are to be identified and subtracted as these areas have more runoff than infiltration. The hilly areas wherever slope is more than 20% may be demarcated using DEM data and geomorphological maps. This would allow the valleys, terraces, plateaus occurring within >20% slope zone to be considered for recharge computations. It is quite likely that with hilly areas, the densely forested area may also be excluded; this may affect to some extent groundwater losses caused due to transpiration by deep-rooted trees in the area of assessment. Apart from this, it is also important that the areas where the quality of groundwater is beyond the usable limits (for drinking water in particular) in terms of salinity are to be identified and handled separately. This methodology recommends that after the assessment is done, a quality flag may be added to the assessment unit for parameters salinity, fluoride, and arsenic. In inhabited hilly areas, where surface and sub-surface runoff is high and generally water level data is missing, it is difficult to compute the various components of the water balance equation. Hence, it is recommended that wherever spring discharge data is available, the same may be assessed as a proxy for 'groundwater resources' in hilly areas. The assessment of spring discharge would constitute the 'replenishable potential groundwater resource' but it will not be accounted for in the categorization of groundwater assessment, at least not in the near future.

The groundwater resource beyond the permissible quality limits in terms of the salinity has to be computed separately. The remaining area after excluding the area with poor groundwater quality is to be delineated as follows:

(a) Non-command areas which do not come under major/medium surface water irrigation schemes. (Command area <100 Ha in the assessment unit should be ignored)

(b) Command areas that come under major/medium surface water irrigation schemes which are supplying water (>100 Ha of command area in the assessment unit.)

It is proposed to have all these areas of an assessment unit in integer hectares to make it national database with uniform precision.

2.5 GROUNDWATER RESOURCES OF AN ASSESSMENT UNIT

The groundwater resources of any assessment unit are the sum of the total groundwater availability in the principal aquifer (mostly unconfined aquifer) and the total groundwater availability of semi-confined and confined aquifers existing in that assessment unit. The total groundwater availability of any aquifer is the sum of dynamic groundwater resources and the in-storage or static resources of the aquifer.

The groundwater resources assessment was carried out based on the guidelines of the Ministry of Water Resources, RD & GR, which broadly follows the methodology recommended by the Groundwater Resources Estimation Committee, 2015. The salient features of the methodology are enumerated in the following paragraphs.

The groundwater recharge is estimated season-wise both for monsoon season and non-monsoon season separately. The following recharge and discharge components are assessed in the resource assessment - recharge from rainfall, recharge from the canal, return flow from irrigation, recharge from tanks and ponds, and recharge from water conservation structures and discharge through groundwater draft.

The groundwater resources of any assessment unit are the sum of the total groundwater availability in the principal aquifer (mostly unconfined aquifer) and the total groundwater availability of semi-confined and confined aquifers existing in that assessment unit. The total groundwater availability of any aquifer is the sum of Dynamic groundwater resources and the In-storage or Static resources of the aquifer.

2.6 GROUNDWATER ASSESSMENT OF UNCONFINED AQUIFER

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

2.6.1 Assessment Of Annually Replenishable Or Dynamic Groundwater Resources

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

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

Equation 1 can be further elaborated as -

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

Where,
ΔS – Change in storage
RRF – Rainfall recharge
RSTR- Recharge from stream channels
Rc – Recharge from canals
RSWI – Recharge from surface water irrigation
RGWI- Recharge from groundwater irrigation
RTP- Recharge from Tanks and Ponds
R_{WCS} – Recharge from water conservation structures
VF – Vertical flow across the aquifer system
LF- Lateral flow along with the aquifer system (through flow)
GE-Groundwater Extraction
T- Transpiration
E- Evaporation
B-Base flow

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

2.6.1.1 Rainfall recharge:

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

2.6.1.2 Groundwater level fluctuation method

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

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

Where,

ΔS – Change in storage R_{RF}

– Rainfall recharge

R_{STR}- Recharge from stream channels

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

R_{GWI}- Recharge from groundwater irrigation

R_{TP}- Recharge from tank and ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical flow across the aquifer system

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

GE-Groundwater Extraction

T- Transpiration

E- Evaporation

B-Base flow

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

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

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

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

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

Where

ΔS – Change in storage

Δh - rise in water level in the monsoon season A - area

for computation of recharge

Sy - Specific Yield

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

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

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

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

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

Normalization of Rainfall Recharge

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

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

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

Where,

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

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

Sy =Specific yield

A = Area for computation of recharge

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

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

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

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

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

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

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

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

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

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

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

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

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

R = ar ……………………….(10)

where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

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

$$R_{rf}(normal) = \frac{\sum_{i=1}^{N}\left[R_i \times \frac{r(normal)}{r_i}\right]}{N} \quad \text{……………………………………………………………… } \mathbf{11}$$

Where,

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

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

r(normal) - Normal monsoon Season rainfall.

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

N - No, of years data is available.

The second method is also based on a linear relation between recharge and rainfall.

However, this linear relationship is of the form,

R = ar+b ………………………………………………………………….(12)

where,

R = Rainfall recharge during monsoon season r

= Monsoon season rainfall

a and b = constants.

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

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2} \quad \text{………………(13)}$$

$$b = \frac{S_2 - aS_1}{N} \quad \text{………………(14)}$$

Where

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

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

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

2.6.1.3 *Rainfall Infiltration Factor method*

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

Recharge from rainfall is estimated by using the following relationship –

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

Where,

R_{rf} = Rainfall recharge in ham A

= Area in Hectares

RFIF = Rainfall Infiltration Factor R

= Rainfall in mm

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

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

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

2.6.1.4 *Percent Deviation*

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

$$PD = \frac{Rrf\,(normal, wtfm) - Rrf\,(normal, rifm)}{Rrf\,(normal, wtfm)} \times 100 \qquad \text{…………………………..(17)}$$

Where,

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

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

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

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

2.6.1.5 *Recharge from other Sources*

Recharge from other sources constitutes recharges from canals, surface water irrigation, groundwater irrigation, tanks and ponds, and water conservation structures in command areas whereas in non-command areas the recharge due to surface water irrigation, groundwater irrigation, tanks and ponds, and water conservation structures are possible.

2.6.1.6 *Recharge from Canals:*

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

R_C=WA * SF * Days …………………………………………………………(18)

Where:

R_C= Recharge from Canals WA=Wetted Area

SF= Seepage Factor

Days= Number of Canal Running Days.

2.6.1.7 *Recharge from Surface Water Irrigation:*

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

R_{SWI} =AD*Days*RFF ………………………………………………………..…. (19)

Where:

R_{SWI} = Recharge due to applied surface water irrigation AD= Average Discharge
Days=Number of days water is discharged to the Fields
RFF= Return Flow Factor

2.6.1.8 *Recharge from Groundwater Irrigation:*

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

R_{GWI} =GE_{IRR}*RFF ……………………………………………………..(20)

Where:

R_{GWI} = Recharge due to applied groundwater irrigation GE_{IRR}= Groundwater Extraction for Irrigation
RFF= Return Flow Factor

2.6.1.9 *Recharge due to Tanks & Ponds:*

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

R_{TP} =AWSA*RF …………………………………………………………..(21)

Where:

R_{TP} = Recharge due to Tanks and Ponds AWSA= Average Water Spread Area RF= Recharge Factor

2.6.1.10 *Recharge due to Water Conservation Structures:*

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

R_{WCS} =GS*RF ……………………………………………………………..…(22)

Where:

R_{WCS} = Recharge due to Water Conservation Structures
GS= Gross Storage = Storage Capacity multiplied by a number of fillings.
RF= Recharge Factor

2.6.1.11 *Lateral flow along with the aquifer system (Throughflow)*

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

2.6.1.12 *Baseflow and Stream Recharge*

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

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

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

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

2.6.1.13 *Vertical Inter Aquifer Flow*

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

2.6.1.14 *Evaporation and Transpiration*

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

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

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

2.6.1.15 Recharge/ Accumulations 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 subunit and stream inflows & outflows during monsoon season is the total recharge/ accumulation during monsoon season for the subunit. Similarly, this is to be computed for all the subunits available in the assessment unit.

2.6.1.16 Recharge/ Accumulations during Non-Monsoon Season

The rainfall recharge during the non-monsoon season is estimated using the 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 subunit and stream inflows & outflows during the non-monsoon season is the total recharge/ accumulation during the non-monsoon season for the subunit. Similarly, this is to be computed for all the subunits available in the assessment unit.

2.6.1.17 Total Annual Ground-Water Recharge

The sum of the recharge/ accumulations during monsoon and non-monsoon seasons is the total annual groundwater recharge/ accumulations for the subunit. Similarly, this is to be computed for all the subunits available in the assessment unit.

2.6.2 Annual Extractable Groundwater Resource (EGR)

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

In case base flow contribution to the ecological flow of rivers is not determined then the following assumption is to be followed. In the water level fluctuation method, a significant portion of the base flow is already accounted for by taking the post-monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, present practice (GEC 1997) of allocation of unaccountable natural discharges to 5% or 10% of annual recharge may be retained. If the rainfall recharge is assessed using the water level fluctuation method this will be 5% of the annual recharge and if it is assessed using the rainfall infiltration factor method, it will be 10% of the annual recharge. The balance will account for Annual Extractable Groundwater Resources (EGR).

2.6.2.1 Estimation of Groundwater Extraction

Groundwater draft or extraction is to be assessed as follows.

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND} \quad ......(23)$$

Where,

GE_{ALL}=Groundwater extraction for all uses

GE_{IRR}=Groundwater extraction for irrigation

GE_{DOM} =Groundwater extraction for domestic uses

GE_{IND} = Groundwater extraction for industrial uses

2.6.2.2 Groundwater Extraction for Irrigation (GE_{IRR}):

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

Unit Draft Method:

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

Crop Water Requirement Method:

For each crop, the season-wise net irrigation water requirement is determined. This is then multiplied with the area irrigated by groundwater abstraction structures. The database on crop area is obtained from Revenue records in the Tehsil office, Agriculture Census, and also by using Remote Sensing techniques.

Power Consumption Method:

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

2.6.2.3 Groundwater Extraction for Domestic Use (GE_{DOM}):

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

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

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

GE_{DOM}= Population X Consumptive Requirement X Lg …………………………….(24)

Where,

Lg = Fractional Load on Groundwater for Domestic Water Supply

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

2.6.2.4 Groundwater 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, the unit draft of each type of well is multiplied by the number of wells used for the industrial purpose to obtain the industrial groundwater extraction.

***Consumptive Use Pattern Method:* –** In this method, the water consumption of different industrial units is determined. The number of Industrial units which are dependent on groundwater is multiplied with unit water consumption to obtain groundwater draft for industrial use.

GE_{IND}= Number of industrial units X Unit Water Consumption X Lg ………. (25)

Where,

Lg = Fractional load on groundwater for industrial water supply

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

Groundwater extraction obtained from different methods need to be compared and based on field checks, the seemingly best value may be adopted. At times, groundwater 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 groundwater extraction during that particular period.

2.6.3 Stage of Groundwater Extraction

The stage of groundwater extraction is defined by,

$$\textit{Stage of Groundwater Extraction}\ (\%) = \frac{\text{Existing gross groundwater extraction for all uses}}{\text{Annual Extractable Groundwater Resources}} * 100 \quad \mathbf{\ldots\ldots\ldots(26)}$$

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

2.6.3.1 Validation of Stage of Groundwater Extraction

The assessment based on the stage of groundwater extraction has inherent uncertainties. The estimation of groundwater extraction is likely to be associated with considerable uncertainties as it is based on indirect assessment using factors such as electricity consumption, well census, and area irrigated from groundwater. The denominator in equation 26, namely Annual Extractable Groundwater Resources also has uncertainties due to limitations in the assessment methodology, as well as uncertainties in the data. In view of this, it is desirable to validate the „Stage of Groundwater Extraction" with long-term trend of groundwater levels.

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

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

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

Table 2 Stage of Ground water Extraction based on Ground water level trend

SOGWE	Groundwater level trend	Remarks
≤70%	Decline trend in both pre-monsoon and post-Monsoon	Not acceptable and needs Reassessment
>100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs Reassessment

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

2.6.3.2 Categorization of Assessment Units

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

2.6.3.3 *Categorization of Assessment Units Based on Quantity:*

The categorization based on the status of groundwater quantity is defined by Stage of Groundwater extraction as given below:

Table 3 Stage of Ground water Extraction based on Quantity

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

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

2.6.3.4 *Categorization of Assessment Units Based on Quality*

GEC 1997 proposed categorization of assessment units based on groundwater extraction only.

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

2.6.4 *Allocation of Groundwater Resource for Utilization*

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

Alloc = 22 X N X L_g mm per year ……………………………………………..…(27)

Where

Alloc= Allocation for domestic water requirement

N = population density in the unit in thousands per sq. km.
L_g = fractional load on groundwater for domestic and industrial water supply (1.0)
In deriving equation 27, it is assumed that the requirement of water for domestic use is 60 lpd per head. The equation can be suitably modified in case if the per capita requirement is different. If by chance, the estimation of projected allocation for future domestic needs is less than the current domestic extraction due to any reason, the allocation must be equal to the present-day extraction. It can never be less than the present-day extraction as it is unrealistic.

2.6.4.1 *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 Groundwater Recharge. The resulting groundwater potential is termed as the net annual groundwater availability for future use. The Net annual groundwater availability for future use should be calculated separately for non-command areas and command areas. As per the recommendations of the R&D Advisory committee, the groundwater 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 groundwater available for future uses will be zero.

2.6.4.2 *Additional Potential Resources under Specific Conditions*

Potential Resource Due to Spring Discharge:

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

Potential groundwater resource due to springs = Q x No of days ………..….(28)
Where
Q = Spring Discharge
No of days= No of days spring yields.

Potential Resource in Waterlogged and Shallow Water Table Areas:

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

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

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

Potential groundwater resource in shallow water table areas = (5-D) x A x S_Y ……..(29)

Where

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

A = Area of shallow water table,zone.

S_Y = Specific Yield

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

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

Potential Resource in Flood-Prone Areas:

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

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

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

Potential groundwater resource in Flood Prone Areas = 1.4 x N x A/1000 ……..(30)

Where

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

Apportioning of Groundwater Assessment from Watershed to Development Unit:

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

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

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

Assessment of In-Storage Groundwater Resources or Static Groundwater Resources

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

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

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

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

Where,

SGWR = Static or in-storage Groundwater Resources

A = Area of the Assessment Unit

Z_2 = Bottom of Unconfined Aquifer

Z_1 = Pre-monsoon water level

S_Y = Specific Yield in the In-storage Zone

Assessment of Total Groundwater Availability in Unconfined Aquifer The sum of Annual Exploitable Groundwater Recharge and the In-storage groundwater resources of an unconfined aquifer is the Total Groundwater Availability of that aquifer.

2.7 GROUNDWATER ASSESSMENT OF CONFINED AQUIFER SYSTEM

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

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

$$\Delta V = S\,\Delta h \qquad \text{................(32)}$$

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

$$Q = A\,\Delta V = SA\,\Delta h \qquad \text{................(33)}$$

Where

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

S = Storativity

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

Δh = Change in Piezometric head (m)

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

$$Q_p = SA\Delta h = SA\,(h_t - h_0) \qquad \text{................(34)}$$

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

Dynamic Groundwater Resources of Confined Aquifer

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

$$\mathbf{Q_D = SA\Delta h = SA\,(h_{POST} - h_{PRE})} \quad \text{……………………………………………..…..(35)}$$

Where

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

S = Storativity

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

Δh = Change in Piezometric head (m)

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

In storage Groundwater Resources of Confined Aquifer

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

$$\mathbf{Q_I = SA\Delta h = SA\,(h_{PRE} - h_0)} \quad \text{……………………………………………….(36)}$$

Where

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

S = Storativity

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

Δh = Change in Piezometric head (m)

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

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

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

$$\mathbf{Q_p = SA\Delta h = SA\,(h_{POST} - h_0)} \quad \text{…………………………………………………..(37)}$$

Where

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

S = Storativity

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

Δh = Change in Piezometric head (m)

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

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

Assessment of Total Groundwater Availability of Confined Aquifer

If the confined aquifer is being exploited, the Total Groundwater Availability of the confined aquifer is the sum of Dynamic Groundwater Resources and the In storage groundwater resources of that confined aquifer whereas if it is not being exploited, the Total Groundwater Availability of the confined aquifer comprises of only one component i.e. the In storage of the confined aquifer.

Groundwater assessment of semi-confined aquifer system

The Assessment of Groundwater Resources of a semi-confined aquifer has some more complications. Unless and until it is well studied that the recharge to this is not computed either in the overlying unconfined aquifer or underlying/overlying semi-confined aquifers, it should not be assessed separately. If it is assessed separately, there is a possibility of duplication of estimating the same resource by direct computation in one aquifer and as leakage in the other aquifer. As it is advisable to underestimate rather than to overestimate the resources, it is recommended not to assess these resources separately as long as there is no study indicating its non-estimation. If it is found through field studies that the resources are not assessed in any of the aquifers in the area, these resources are to be assessed following the methodology similar to that used in assessing the resources of Confined aquifers.

Total groundwater availability of an area

The Total Groundwater availability in any area is the Sum of Dynamic Groundwater Resources, the total static/ in-storage groundwater resources in the unconfined aquifer, and the dynamic and In-storage resources of the Confined aquifers and semi-confined aquifers in the area.

Groundwater assessment in urban areas

The Assessment of Groundwater 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 groundwater abstraction structures are available, accuracy is somewhat doubtful and individuals cannot even enumerate the good census in urban areas. Hence it is recommended to use the difference of the actual demand and the supply by surface water sources as the withdrawal from the groundwater resources.

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, it is proposed to use 30% of the rainfall infiltration factor proposed 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 is also to be included in the other resources and the recharge may be estimated. The percent losses may be collected from the individual water supply agencies, 50% of which can be taken as recharge to the groundwater 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 groundwater reservoir. As of today, there is no documented field study to assess the recharge. The seepages from the sewerages, which normally contaminate the groundwater resources with nitrate also contribute to the number of resources and hence the same percent as in the case of water supply pipes may be taken as a norm for the recharge on the quantity of sewerage when there is subsurface drainage system. If estimated flash flood data is available, the same percentage can be used on the quantum of flash floods to estimate the recharge from the flash floods. Even when the drainage system is open channels, till further documented field studies are done same procedure may be followed.

It is proposed to have a separate groundwater assessment for urban areas with a population of more than 10 lakhs.

Groundwater assessment in coastal areas

The Assessment of Groundwater Resources in coastal areas is similar to that of other areas. Because of the nature of hydraulic equilibrium of groundwater with seawater care should be taken in assessing the groundwater resources of this area. While assessing the resources in these areas, the following few points are to be considered.

The groundwater resources assessment in coastal areas includes the areas where the influence of seawater has an effect on the existence of fresh water in the area. It can be demarcated from the Coastal Regulatory zone or the Geomorphological maps or from the maps where seawater influences are demarcated.

Wherever the pre-monsoon and post-monsoon water levels are above mean sea level the dynamic component of the estimation will be the same as other areas.

If both these water levels are below sea level, the dynamic component should be taken as zero.

Wherever the post-monsoon water table is above sea level and the pre-monsoon water table is below sea level the pre-monsoon water table should be taken as at sea level and fluctuation is to be computed.

The static or in-storage resources are to be restricted to a minimum of 40 times the pre-monsoon water table or the bottom of the aquifer.

Groundwater assessment in water level depletion zones

There may be areas where groundwater 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 groundwater regime, with groundwater extraction and natural groundwater discharge in the monsoon season (outflow from the region and baseflow) exceeding the recharge. (b) There may be an error in water level data due to the inadequacy of observation wells.

If it is concluded that the water level data is erroneous, recharge assessment may be made based on the rainfall infiltration factor method. If, on the other hand, water level data is assessed as reliable, the groundwater level fluctuation method may be applied for recharge estimation. As ΔS in Equations 3& 4 is negative, the estimated recharge will be less than the gross groundwater 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 will be that the area falls under the over-exploited category which requires micro-level study.

Micro-level study for notified areas

In all areas which are 'Notified' for groundwater regulation by the Central and/ or State Groundwater Authorities, it is necessary to increase the density of observation wells for carrying out micro-level studies to reassess the groundwater recharge and draft. The following approach may be adopted:

1. The area may be sub-divided into different hydrogeological sub-areas and recharge areas, discharge areas, and transition zone and also on quality terms.
2. The number of observation wells should be increased to represent each such sub-areas with at least one observation well with continuous monitoring of water levels.
3. Hydrological and hydrogeological parameters particularly the specific yield should be collected for different formations in each sub-area.
4. Details regarding other parameters like seepage factor from canals and other surface water projects should be collected after field studies, instead of adopting recommended norms. Baseflow should be estimated based on stream gauge measurement.
5. The data of a number of existing structures and unit drafts should be reassessed after fresh surveys and should match with the actual irrigation pattern in the sub-area.
6. All data available with Central Groundwater Board, State Groundwater Departments, and other agencies including research institutions and universities, etc. should be collected for the watershed/sub-areas and utilized for reassessment.
7. Groundwater assessment for each sub-area may be computed adopting the recommended methodology and freshly collected values of different parameters. The assessment may be made separately for monsoon and non-monsoon periods as well as for command,non-command, and poor groundwater quality areas.
8. The groundwater potential so worked out maybe cross-checked with the behavior of groundwater levels in the observation wells and both should match. If it does not, the factor that causes such an anomaly should be identified and the revised assessment should be re-examined.
9. Based on the micro-level studies, the sub-areas within the unit and the unit as a whole may be classified adopting norms for categorization as recommended elsewhere in the methodology.

Norms to be used in the assessment

The committee recommends that the state agencies should be encouraged to conduct field studies and use these computed norms in the assessment. For conducting field studies, it is recommended to follow the field-tested procedures for computing the norms. There is the possibility of error creeping in at various levels in the field study and hence the committee is of the opinion to give maximum and minimum values for all the norms used in the estimation. The committee can foresee the handicap of the state agencies which are not able to compute the norms by their own field study. In such cases, it suggests an average of the range of norms to be used as the recommended value for the norm. This has been further clarified in the following paragraphs.

Specific Yield

Recently under Aquifer Mapping Project, Central Groundwater Board has classified all the aquifers into 16 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 Major aquifer map can be obtained from the Regional offices of the Central Groundwater Board.

The recommended Specific Yield values are to be used for assessment unless sufficient data based on field studies are available to justify the minimum, maximum, or other intermediate values. The Norms suggested below are nothing but the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Rainfall Infiltration Factor

It is recommended that to assign Rainfall Infiltration Factor values to all the aquifer units recently classified by the Central Groundwater Board. The recommended Rainfall Infiltration Factor values are to be used for assessment unless sufficient data based on field studies are available to justify the minimum, maximum or other intermediate values. An additional 2% of rainfall recharge factor may be used in such areas or parts of the areas where watershed development with associated soil conservation measures are implemented. This additional factor is subjective and is separate from the contribution due to the water conservation structures such as check dams, nalla bunds, percolation tanks etc. The norms for the estimation of recharge due to these structures are provided separately. This additional factor of 2% is at this stage, only provisional, and will need revision based on pilot studies.

The Norms suggested below are the redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Norms for Canal Recharge

Unlike other norms, the Recharge factor for calculating Recharge due to canals is given in two units viz. ham/million m^2 of wetted area/day and cumecs per million m2 of wetted area. As all other norms are in ham, the committee recommends the norm in ham/million m2 of wetted area for computing the recharge due to canals. There is a wide variation in the values of the recharge norms proposed by GEC 1997. The Canal seepage norm is approximately 150times the other recharge norms. In the absence of any field studies to refine the norms it is decided by the committee to continue with the same norms. The committee strongly recommends that each state agency must conduct one filed study at least one in each district before completing the first assessment using this methodology. The committee also suggests a recommended value and minimum and maximum values as in the case of other norms. Where specific results are available from case studies in some states, the Adhoc norms are to be replaced by norms evolved from these results.

The Norms suggested in Table 9 below are the rationalization and redistribution of norms suggested by GEC-1997 methodology and hence people are encouraged to conduct field studies and strengthen the Norms database.

Norms for Recharge Due to Irrigation

The Norms Suggested by GEC-1997 give for only three ranges of water levels and it creates a problem in the boundary conditions. For instance, as a result of the variation in water level from 24.9 to 25.1m bgl in the adjoining blocks, change occurs in the return flow from irrigation in the range of 10% to 15%. Hence to reduce the discrepancy it is recommended to have a linear relationship of the norms in between 10m bgl water level and 25m bgl water level. It is proposed to have the same norm of 10m bgl zone for all the water levels less than 10m. Similarly, the norm recommended for 25m may be used for the water levels more than 25m as well. The Recommended Norms are presented in Table 10.

For surface water, the recharge is to be estimated based on water released at the outlet. For groundwater, the recharge is to be estimated based on a gross draft. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used. Where specific results are available from case studies in some states, the Adhoc norms are to be replaced by norms evolved from these results.

Norms for Recharge due to Tanks & Ponds

As the data on the field studies for computing recharge from Tanks & Ponds are very limited, it is recommended to follow the same norm as followed in GEC 1997in future assessments also. Hence the norm recommended by GEC-2015 for Seepage from Tanks & Ponds is 1.4 mm / day.

Norms for Recharge due to Water Conservation Structures

Even though the data on the field studies for computing recharge from Water Conservation Structures are very limited, it is recommended that the Recharge from the water conservation structures is 40% of the Gross Storage based on the field studies by Non-Government Organizations. Hence, the norm recommended by GEC-2015 for the seepage from Water Conservation Structures is40% of gross storage during a year which means 20% during monsoon season and 20% during non-monsoon Season.

Norm for Per Capita Requirement

As the option is given to use the actual requirement for domestic needs, the Requirement Norm recommended by the committee is 60 lpcd for domestic needs. This can be modified if the actual requirement is known.

Norm for Natural Discharges

The Discharge Norm used in computing Unaccounted Natural Discharge is 5% if the water table fluctuation method is used or 10% if the rainfall infiltration factor method is used for assessing the Rainfall recharge. This committee recommends computing the base flow for each assessment unit. Wherever, there is no assessment of base flow, earlier norms recommended by GEC 1997ie. 5% or 10% of the Total Annual Groundwater Recharge as the Natural discharge may be continued.

Unit Draft

GEC-1997 methodology recommends using well census method for computing the groundwater draft. The norm used for computing groundwater draft is the unit draft. The unit draft can be computed by field studies. This method involves selecting representative abstraction structures 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 the number of such days during each season. The Unit Draft during a particular season can be computed using the following equation:

$$Unit\ Draft = Discharge\ in\ m^3/hr \times No.of\ Pumping\ hrs\ in\ a\ day \times No.of\ days \qquad \textbf{38}$$

One basic drawback in the methodology of computing unit draft is that there is no normalization procedure for the same. As per GEC-1997 guidelines, the recharge from rainfall is normalized for normal rainfall. It means that even though the resources are estimated in a surplus rainfall year or in a deficit rainfall year, the assessment is normalized for a normal rainfall which is required for planning. For recharge from other sources, average figures/ values are taken. If the average figures are not available for any reason,60% of the design figures are taken. This procedure is very much essential as the planning should be for average resources rather than for the recharge due to excess rainfall or deficit rainfall. But the procedure that is being followed for the 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 groundwater 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 can be followed. If the unit draft values for one rainfall cycle are available for at least 10 years second method shown in equation 40 is to be followed or else the first method shown in equation 39 may be used.

$$Normalized\ Unit\ Draft = \frac{Unit\ Draft \times Rainfall\ for\ the\ Year}{Normal\ Rainfall} \qquad \textbf{39}$$

$$Normalized\ Unit\ Draft = \frac{\sum_{i=1}^{n} Unit\ Draft_i}{Number\ of\ Years} \qquad \textbf{40}$$

Although the GEC-1997 methodology recommends a default value for the unit drafts, each State is using its values, generally after conducting field studies, even though without documentation. Hence, it is felt that this norm may be computed by the state agency, which is going to assess the norms before the commencement of the assessment. But it is strongly recommended that the field studies should be documented and submitted along with the results of the assessment.

CHAPTER – 3
PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT INCLUDING ASSUMPTIONS

3.1 DYNAMIC GROUNDWATER RESOURCES ESTIMATION

The Dynamic Groundwater Resource of Ladakh UT has been assessed as per GEC-2015 Methodology by taking Block as a Unit of Assessment. At present, there are total of 2 Districts in Ladakh UT, however, in the present study 2 Districts have been considered which represents the entire geographical area of the state. The block boundaries and other technical details in respect of Districts are not available. The Minor Irrigation Census for Tube wells for the year 2006-07 has been carried out by the Agriculture Department for 2 Districts. As such, 2 Districts has been considered (Refer **Fig–1** for Administrative Base Map) for this study, making an assessment of Dynamic Groundwater Resource for which the multidisciplinary data have been provided by the following Agencies:

1. Central Groundwater Board, North Western Himalayan Region, Jammu.
2. Irrigation & Flood Control Department, Ladakh.
3. Public Health Engineering Department, Ladakh.
4. Agriculture Department Ladakh.
5. Indian Meteorological Department, Pune, and Jammu and Kashmir
6. Industries Department Ladakh
7. NABARD Ladakh

The water level data for the year 2015-19 has been used to calculate average monsoon recharge, which has been normalized as per GEC-2015 guidelines. The unit draft figures for the year 2013-19 on a pro-rata basis have been made available by the Agriculture and Irrigation & Flood Control Department and part from Digest of Statistics of J& K year 2017-18. The block-wise figures of population provided by the Census Department GOI have been used as per census 2011. The per capita consumption of water is taken as 100 lpd for assessing the domestic use requirement of groundwater as per detailed deliberations held during various meetings. The percentage increase in district-wise population w.r.t. 2011 census has been applied for calculating the present and future domestic requirements. The district-wise water use requirement figures for Industry as supplied by the Department of Industries, Ladakh for the year 2019 have been used by projecting the data on a pro-rata basis of population growth rate, i.e., 1.5% per annum. Many new changes/modifications have been incorporated in the network of canals in the Ladakh UT, So the canal data has been obtained from the various Canal Divisional Offices and I & FC Department; Ladakh have been updated and taken into the calculations.

The value of Specific Yield for calculating the Dynamic Groundwater Resource of the UT has been taken as 02 to 20%, which is within the norms provided in the guidelines of GEC-2015 issued by the Ministry of Water Resources, River Development, and Ganga Rejuvenation, Govt. of India.

While calculating the groundwater resources of the State, GEC -2015 methodology along with its amendments has been used with the following parameters/assumptions: -

1. The various dependency factors for the calculation of domestic groundwater consumption have been taken from the GEC-2015 Methodology of CGWB.
2. The various modifications have been incorporated based on the various inputs made available from CGWB, Agriculture, Irrigation, University's Department of Jammu and Kashmir, and other agencies associated with this estimation.

<u>The present estimation is as follows: -</u>

i. The geographical area of Districts is taken from the digest of the statistic year 2016-17, wherein certain discrepancy in boundary areas, however, with the information given in the form of the digitized boundary of each district were utilized to arrive at total geographical area of districts. Out of which, part of the valley and the hilly regions were demarcated using toposheets and updated Digital Elevation Model (DEM) data taken from various resources. In the hilly region, the geographical area calculated by using DEM data and Toposheets after demarcation of the hilly area, later on, is confined to 20m contour elevation from bottom of the valley towards hill has been considered for groundwater worthy area in the Groundwater Estimation.
ii. A uniform value of Specific Yield has been adapted instead of soil-related value. The value of Sp. Yield, as adopted has been taken in between 02-20% for Ladakh UT.
iii. The canal seepage factor for unlined canals may be taken as 17.5 ha /day/million sq. mts. and 3.5 ha m/day/million sq. mts. for lined canals as recommended by GEC-2015.

For this report, the Agriculture Department and Digest of Statistics have supplied district-wise areas under Paddy/Non-Paddy crops on a pro-rata basis. Data for the Number of Tube wells were supplied by the Agriculture Department, Irrigation & Flood Control Department, and Digest of Statistic.

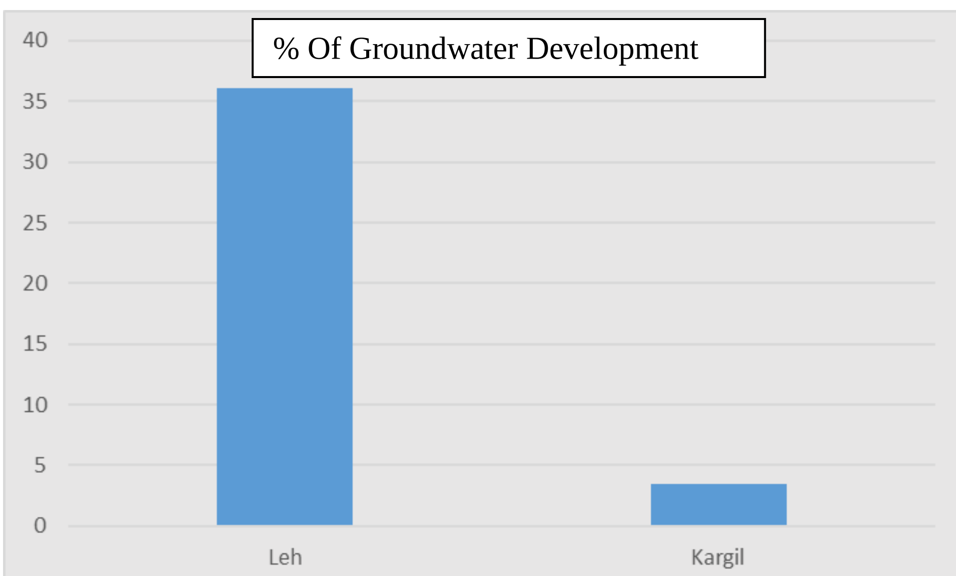
i. For this report, the Agriculture Department and Digest of Statistics have supplied district-wise areas under Paddy/Non-Paddy crops on a pro-rata basis. Data for the Number of Tube wells were supplied by the Agriculture Department, Irrigation & Flood Control Department, and Digest of Statistic (2019-2020).
ii. The District-wise industrial draft figures supplied by the Department of Industry and digest of statistic has been used in this report as new data not supplied by Department of Industry. It was decided that the Groundwater Extraction by industries may be calculated as per the growth rate of 1.5% per annum on a pro-rata basis of population growth rate i.e. 1.5% per annum.
iii. The domestic draft has been calculated on a population basis @ 100 lpd and also includes demand for the next 25 years. The groundwater dependency factor of 0.8 is taken into consideration for the estimation of future requirements.
iv. G.E.C-1997 requires that the average value of water level at 5 different points in a district be considered for the calculation of seasonal fluctuation. The same condition has also been applied in the present study.
v. Updated Canal data, as received from the Canal Circle / Division Offices during 2019-20 has been used in the estimation.
vi. District where more than 96.5% of its geographical area is having groundwater level less than 5 m (below ground level) have been considered as "Safe".

CHAPTER – 4
COMPUTATION OF GROUNDWATER RESOURCES ESTIMATION IN UT OF LADAKH

4.1 SALIENT FEATURES OF DYNAMIC GROUNDWATER RESOURCES ASSESSMENT

Type of Assessment Units	District
No. of Assessment Units taken for Study	02
Years of Collection of Data (5 years)	2015-19
Year of Projection of Report	2020
No. of Over-Exploited District	0
No. of Critical District	0
No. of Semi-Critical District	0
No. of Safe District	02

Out of total 02 Districts taken for study, "Over-Exploited," Nil District are "Critical," Nil District is "Semi-Critical," and 02 Districts (100%) are in "Safe" category. The percentage of Districts under different categories is represented in the graph below**.** The water level trends have been computed for the last ten years from 2010 – 2019 data.



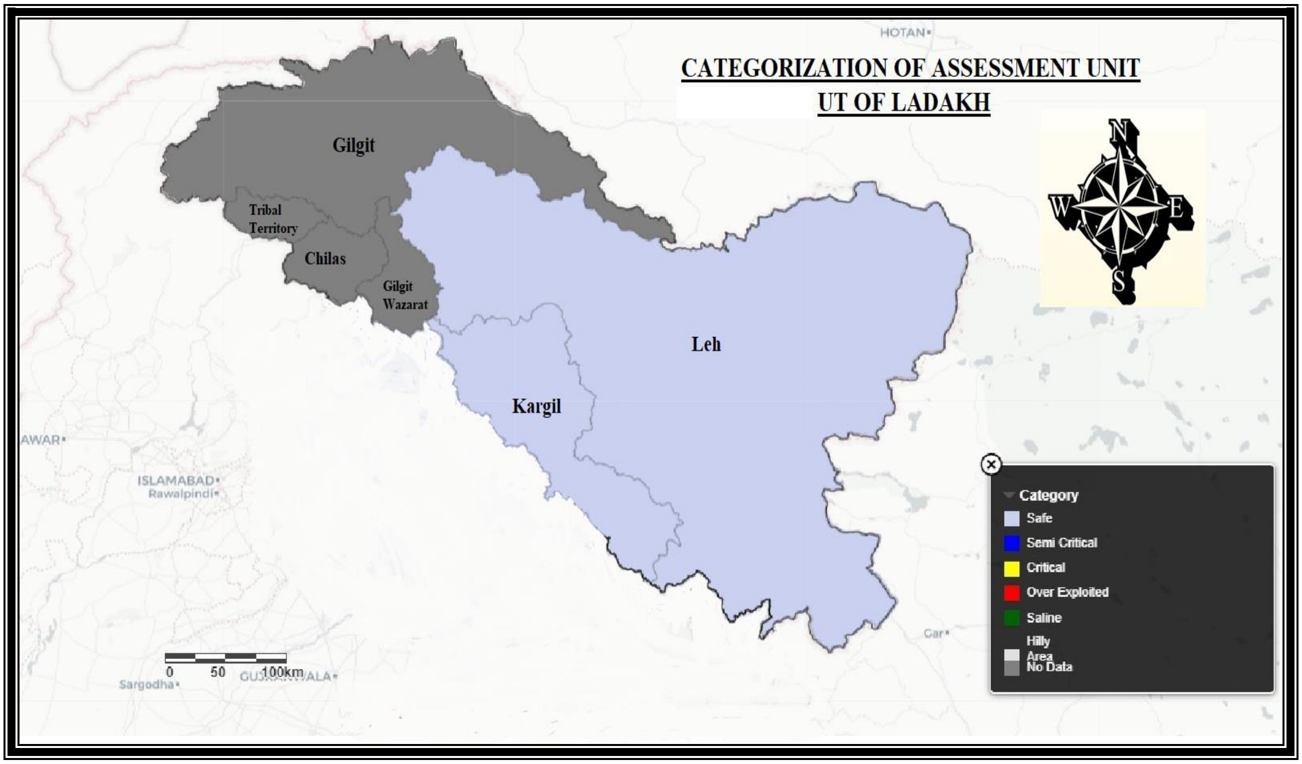


Figure 2 Categorization of Assessment Unit of Ladakh UT

4.1 METHOD ADOPTED FOR COMPUTING RAINFALL RECHARGE DURING MONSOON SEASON

The administrative District has been taken as an assessment unit and for computing the district rainfall recharge during monsoon season. The rainfall Infiltration Factor (RIF) Method has been mostly applied as the difference of computing this with Water Level Fluctuations (WLF) Method. WLF Method was not considered due to random and erratic data and found to be not much decline tread for study. The district-wise details of the method applied for rainfall recharge during the monsoon season are shown in **Annexure IV**.

4.2 GROUNDWATER RESOURCE ASSESSMENT

The groundwater resource assessment of Ladakh UT has been computed as per GEC-15 Methodology and the computations and their various details have been attached as **Annexure I to Annexure III**. The abstract of Dynamic Groundwater Assessment is as follows: -

Table 4 Abstract of Dynamic Groundwater Assessment

Net Annual Groundwater Availability	**10609.57 HAM**
Existing GW Draft for Irrigation	**114.077 HAM**
Existing GW Draft for Industrial & Domestic Use	**1784 HAM**
Existing GW Draft for All Uses	**1899 HAM**
Net GW Availability for Future Irrigation Development	**8617.282 HAM**
Average Stage of GW Extraction of State	**17.90 %**

- The Net Annual Groundwater Availability for the period 2020 works out to be 10609.57 HAM. The Average Normal Recharge figures for all the districts from rainfall and other sources have been calculated and indicated in **Annexure- II.**
- The gross groundwater draft for all uses has been worked out to be 1899 Ham. The existing gross groundwater draft for all uses has been observed to be maximum in Leh district as 1697.87 Ham and minimum in Kargil district as 200.86 Ham. The district-wise groundwater draft for irrigation and other uses (domestic and industrial use) is given in **Annexure-III.** Domestic and Industrial water use demand for the next 25 years have been taken in this estimation.
- The district-wise groundwater availability of Ladakh UT vis-a-vis the groundwater draft and net groundwater availability for future irrigation Development have been depicted in **Annexure-VI**. It has been observed that the net groundwater availability for future irrigation development in the UT is 8617.26 Ham as the state as a whole is "Safe".
- The district-Wise stage of groundwater development varies from 36.13 % in Kargil district to a maximum of 3.40 % in Leh district **(Annexure-IV)**.

4.3 GROUNDWATER ASSESSMENT COMPARISON OF VARIOUS STUDIES

The number of Districts category of overexploited/critical/semi-critical/safe time as per various Groundwater Estimation Studies carried out from time to time, as shown below in:

Table 5 Groundwater Assessment Comparison

Study Year	**2004**	**2009**	**2011**	**2013**	**2017**	**2020**
Category of District						
Dark / Over- exploited	**-**	**-**	**-**	**-**	**-**	**-**
Dark /Critical	**-**	**-**	**-**	**-**	**-**	**-**
Grey / Semi Critical	**-**	**-**	**-**	**-**	**-**	**-**
White/ Safe	**2**	**2**	**2**	**2**	**2**	**2**
Total	**2**	**2**	**2**	**2**	**2**	**2**

4.4 SPATIAL VARIATION OF GROUNDWATER RECHARGE AND DEVELOPMENT SCENARIO

The annual groundwater recharge and the method adopted for computing monsoon recharge for the previous 2013 study and for the present 2017 study have been compared in **Annexure-IV.** Similarly, Categorization for Future Groundwater Development and the Stage of Groundwater development for each block and district of this study as a whole has also been compared with the previous 2013 study as shown in **Annexure-VIII.**

4.5 COMPARISON WITH EARLIER GROUNDWATER RESOURCE ESTIMATE

It has been observed that out of the total area of the State (59,09,700 Ha) the area where the groundwater table is more than 10m deep has been continuously increasing.

4.6 TOTAL GROUNDWATER AVAILABILITY

The Total Groundwater availability (Dynamic and Static) in Ladakh UT is worked out to be 847313.57 Ham. Total availability of Groundwater Resources figures for all the districts have been calculated and indicated in **Annexure- IV and Annexure VII**.

4.7 CHARACTERIZATION OF DISTRICT BASED ON POTENTIALITY

Block wise unit recharge has been calculated by using **Annexure- I and Annexure IV** i.e., Total Annual Groundwater Recharge (Col. 8 of Annexure-IV) divided by the Area of Assessment (Col. 6 of Annexure-I).

$$= \frac{\text{Total Annual Groundwater Recharge (Col. 8 of Annexure-IV)}}{\text{Area of Assessment (Col. 6 of Annexure- I)}}$$

The district-wise calculations have been done on the above formula and the district has been categorized as Highly Potential and Moderately Potential. The same has been shown in **Annexure- IV**

CHAPTER – 5
QUALITY TAG

GENERAL

GEC, 2015 recommends that each assessment unit, in addition to the quantity-based categorization, should bear a quality hazard identifier. If any of the quality hazards in terms of Arsenic, Fluoride, and Salinity are encountered in the assessment subunit in mappable units, the assessment unit may be tagged with the particular hazard.

5.1 ELECTRICAL CONDUCTANCE (E.C)

The electrical conductivity of the Leh district varies between 90 (µs/cm) to 480 (µs/cm), whereas in the Kargil district, it varies between 90(µs/cm) to1270(µs/cm). 1270(µs/cm) at Ratnaksha.

5.2 TOTAL HARDNESS – TH (as $CaCO_3$)

The electrical conductivity of the Leh district varies between 76 mg/lt to 152 mg/lt, whereas in the Kargil district, it varies between 43 mg/lt to 890 mg/lt. 890 mg/lt at Ratnaksha.

5.3 FLUORIDE (F)

The electrical conductivity of the Leh district varies between 0.16 mg/lt to 1.33 mg/lt.

5.4 ARSENIC (As)

No data Available

ANNEXURE 1 GENERAL DESCRIPTION OF THE ADMINISTRATIVE UNIT OF THE LADAKH UNION TERRITORY as on 01.3.2021										
S. No.	Name of Assessment Unit (Part of district)	Type of rock formation	Areal Extent (in Hectares)							
					Groundwater Recharge Worthy Area		Shallow Water Table Area	Flood Prone Area	Bottom of the unconfined aquifer in soft rock areas and depth of weathered zone and/or maximum depth of fractures under unconfined zone(m)
			Total Geographical Area	Hilly Area	Command Area/Non-Command Area	Poor Groundwater Quality Area			
1	**2**	**3**	**4**	**5**	**6**	**8**	**9**	**10**	**11**
1	**Leh**	Alluvial Soil	4511000	4439600	71400	NIL	NIL	NIL	70
2	**Kargil**	Alluvial Soil	1403600	1383600	20000	NIL	NIL	NIL	8
			5914600	**5823200**	**91400**				

ANNEXURE 2 DATA VARIABLES USED IN DYNAMIC GROUNDWATER RESOURCES OF THE LADAKH UNION TERRITORY, as on 31.3.2020						
Sr.No	Assessment Unit	Poor GW Quality	Rainfall (mm)	Average Pre-Monsoon Water Level (mbgl)	Average Post-Monsoon Water Level (mbgl)	Average Fluctuation (m)
1	**2**	**3**	**4**	**5**	**6**	**7**
1	**Leh**	0	87	NA	NA	NA
2	**Kargil**	0	337	NA	NA	NA

ANNEXURE 2(Cont) DATA VARIABLES USED IN DYNAMIC GROUNDWATER RESOURCES OF THE LADAKH UNION TERRITORY, as on 31.3.2020						
S. N.	**Assessment Unit**	**Assessment Sub-Unit**	**Type of Structures**	**Irrigation**	**Domestic**	**Industrial**
1	**Leh**	Non Commanad	STW (ELECTRIC & DIESEL)	26	151	15
2	**Kargil**	Non Commanad	STW (ELECTRIC & DIESEL)	7	50	3

ANNEXURE 3 PARAMETERS USED IN THE ASSESSMENT OF DYNAMIC GROUNDWATER RESOURCES OF THE LADAKH UNION TERRITORY, as on 31.3.2020										
S.No.	**Assessment unit**	**Sub-unit (Command/non-Command/poor quality)**	**Specific Yield (in Percentage**	**Rainfall Infiltration Factor (in Percentage)**	**Groundwater Draft (in ham)**					
			Formation Value	**Formation Value**	**Irrigation**		**Domestic**		**Industrial**	
					Monsoon	**Non-Monsoon**	**Monsoon**	**Non-Monsoon**	**Monsoon**	**Non-Monsoon**
1	**Leh**	Nil	16	22	40.44	49.42	523.81	1063.50	6.83	13.87
2	**Kargil**	Nil	16	22	10.89	13.31	57.02	115.78	1.37	2.77

ANNEXURE 4 ASSESSMENT OF DYNAMIC GROUNDWATER RESOURCES OF THE LADAKH UNION TERRITORY, as on 31.3.2020										
S. No.	**Assessment Unit (Block)/District**	**Command/non-Command/Total (Hac.)**	**Recharge from rainfall during monsoon season (ham)**	**Recharge from other sources during monsoon season (ham)**	**Recharge from rainfall during non-monsoon season (ham)**	**Recharge from other sources during non-monsoon season (ham)**	**Total annual Ground water Recharge (ham) (4+5+6+7)**	**Provision for Natural Discharges (ham)**	**Net Annual Groundwater Availability (ham) (8-9)**	**Method Adopted for Computing Rainfall Recharge during Monsoon**
1	**Leh**	71400	531.40	2071.21	683.77	1934.58	5220.96	522.10	4698.86	RIF METHOD
2	**Kargil**	20000	509.74	2571.17	1180.83	2305.70	6567.44	656.74	5910.70	RIF METHOD
	Total:	**91400**	**1041.14**	**4642.38**	**1864.6**	**4240.28**	**11788.4**	**1178.84**	**10609.56**	

ANNEXURE 4 (Contd.) ASSESSMENT OF DYNAMIC GROUNDWATER RESOURCES OF THE LADAKH UNION TERRITORY, as on 31.3.2020 (in ham)									
S. No.	**Assessment Unit/Distict**	**Command/non-Command/Total (Hac.)**	**Net Annual Groundwater Availability**	**Existing Gross Groundwater Draft for irrigation**	**Existing Gross Groundwater Draft for domestic and industrial water supply**	**Existing Gross Groundwater Draft for all uses (5+6)**	**Provision for domestic, and industrial requirement supply to 2025 years**	**Net Annual Groundwater Availability for future irrigation development (4-5-8)**	**Stage of Groundwater Development 7/4*100 (%)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
11	**Leh**	71400	4698.86	89.86	1608.01	1697.87	1587.31	3,021.69	36.13
12	**Kargil**	20000	5910.70	24.19	176.94	201.13	290.92	5,595.59	3.40
	Total:	**91400**	**10609.56**	**114.048**	**1784.952**	**1899**	**1878.23**	**8617.26**	**17.9**

ANNEXURE 5 ASSESSMENT OF DYNAMIC GROUNDWATER RESOURCES OF THE OF THE LADAKH UNION TERRITORY ASSESSMENT UNIT-WISE CATEGORIZATION as on 31.3.2020								
Sr. No	**Assessment Unit (Block)/ District**	**Stage of Groundwater Development (%)**	**Pre-monsoon**	**Post-monsoon**	**Categorization for future groundwater development (Safe/semi-critical /critcal/over-exploited**	**Pre-monsoon**	**Post-monsoon**	**Remarks**
			Water level Trend Is there a significant decline (Yes/No)	**Water level Trend Is there a significant decline (Yes/No)**		**Water level (cm/yr)**	**Water level (cm/yr)**	
1	**Leh**	36.13	Not Available	Not Available	SAFE	Not Available	Not Available	
2	**Kargil**	3.40	Not Available	Not Available	SAFE	Not Available	Not Available	

ANNEXURE 6 COMPARISON OF STAGE OF GROUNDWATER EXTRACTION & CATEGORIZATION OF PREVIOUS AND PRESENT STUDY, LADAKH UNION TERRITORY									
Sr. No	**Assessment Unit (Block)/ District**	**Stage of Groundwater Development (%)**						**Categorization for future groundwater development (Safe/semi-critical /critcal/over-exploited**	**Remarks**
		2004	**2009**	**2011**	**2013**	**2017**	**2020**		
11	**Leh**	**NA**	**1.33**	**1.4**	**3.79**	**18.66**	**36.13**	**SAFE**	
12	**Kargil**	**NA**	**8.5**	**9.26**	**4.26**	**13.78**	**3.40**	**SAFE**	
	Total:	**0**	**4.915**	**5.33**	**4.025**	**16.22**	**17.90**	**SAFE**	

Annexure 7 COMPARISON & CATEGORISATION OF STAGE OF GROUNDWATER DEVELOPMENT ROM 2009 TO 2020

Assessment Unit (Block)/ District		2009				2011				2013				2017				2020			
	Area in hectare (Consider for Groundwater Recharge)	Existing Gross Groundwater Draft for all uses	Net Annual Groundwater Availability (ham)	Stage of GW Dev (%)	Category	Existing Gross Groundwater Draft for all uses	Net Annual Groundwater Availability (ham)	Stage of GW Dev (%)	Category	Total Draft in (ham)	Net Annual Groundwater Availability (ham)	Stage of GW Dev (%)	Category	Total Draft in (ham)	Net Annual Groundwater Availability (ham)	Stage of GW Dev (%)	Category	Total Draft in (ham)	Net Annual Groundwater Availability (ham)	Stage of GW Dev. (%)	Category
Leh	628000	4403.27	4318.07	1.33	Safe	51.60	3693.98	1.40	Safe	130.60	3449.55	4.26	Safe	89.86	9100.31	18.66	Safe	1697.87	4698.86	36.13	Safe
Kargil	10000	1552.75	1341.55	8.50	Safe	132.00	1425.05	9.26	Safe	138.00	3241.55	3.79	Safe	24.19	632.06	13.78	Safe	201.13	5910.70	3.40	Safe
Total:	638000	5956.02	5659.62	4.92	Safe	183.60	5119.03	5.33	Safe	268.60	6691.10	4.03	Safe	114.05	9732.37	16.22	Safe	1899.00	10609.56	17.90	Safe

I/37/2020

F.No.U.O.Com.Secy(PS)15/PHE/I&FC/2020
THE ADMINISTRATION OF UNION TERRITORY OF LADAKH
GENERAL ADMINISTRATION DEPARTMENT
Civil Secretariat Ladakh
E-mail Id: gadutladakh@gmail.com

Civil Secretariat, UT Ladakh
Dated: 07.12. 2020

Subject: - Constitution of Union Territory Level Committee for estimation of Ground Water Resources for the UT of Ladakh.

Order No:-111–LA(GAD) of 2020
Dated: 07.12. 2020

Sanction is hereby accorded to the constitution of Union Territory Level Committee comprising the following, for estimation of Ground Water Resources in the Union Territory of Ladakh for the year 2019-20:-

1.	Administrative Secretary, PHE/I&FC Department.	Chairman
2.	Chief Engineer, PHE/I&FC Department.	Member
3.	Director, Rural Development Department.	Member
4.	Director, Agriculture/Horticulture Department.	Member
5.	Director, Industries & Commerce Department.	Member
6.	Regional Director, Central Ground Water Board, Jammu.	Member-Secretary
7.	Any other officer to be co-opted by the Chairman of the committee, if required.	Special Invitee

Terms of Reference of the Committee shall be:

i) To assess annual water recharge of the UT in accordance with the Ground Water Resources Estimation Methodology-2015;

ii) To estimate the status of utilization of the annual extractable Ground Water Resources.

The Committee shall be serviced by the PHE/I&FC Department.

Further, sanction is also accorded to the nomination of Chief Engineer, PHE/I&FC Department, Ladakh as Nodal Officer for coordination and providing of required data during the compilation of above report.

By order of Lieutenant Governor Ladakh.

Sd/-
(Ajeet Kumar Sahu) IAS
Commissioner/ Secretary
General Administration Department

7.12.2020

Copy: As above.

Copy also to the: -

1. All Administrative Secretaries, Civil Secretariat, Ladakh.
2. District Superintending Engineer, PHE/I&FC Department, Leh/Kargil.
3. Deputy Secretary, PHE/I&FC Department, Civil Secretariat Ladakh. The departmental U.O. file is also returned herewith.
4. District Informatics Officer, NIC Ladakh for uploading on UT Ladakh website.
5. OSD to Hon'ble Lieutenant Governor, for information of HLG, Ladakh.
6. Private Secretary to Advisor to Hon'ble Lt. Governor for information of Advisor to Hon'ble Lt. Governor.
7. Office/ Order/e-office file.

7.12.2020

(Sonam Chhosdon)
Under Secretary,
General Administration Department

The Administration of Union Territory of Ladakh
PHE/I&FC Department
Civil Secretariat, Ladakh

****

Sh. Ashok Kumar
Head of Office &
Member Secretary

Subject:- Draft minutes of 1st Meeting of UT Level Committee for Ground Water Resource Estimation for UT of Ladakh, as on 31st March, 2020 held on 16.12.2020 for approval-reg.

Sir,

This takes reference to your Letter No. TC-22/NWHR/GWRE/2020-615 Dated: 17.12.2020 (**copy enclosed**) seeking approval for "Draft minutes of 1st Meeting of UT Level Committee for Ground Water Resource Estimation for UT of Ladakh, as on 31st March, 2020 held on 16.12.2020".

Accordingly, I am directed to convey the approval for further necessary action at your end.

Yours faithfully,

10/2/21

(Delex Namgyal) KAS,
(I/c Dy. Secretary to the Administration)
PHE/I&FC Department.

No:LA(UT)/PHE/I&FC//2020-21/312-13 Dated:10.02.2021

Copy to the:-

1. PS for kind information of Commissioner/Secretary, PHE/I&FC Department, Ladakh.
2. Office File.

THE ADMINISTRATION OF UNION TERRITORY OF LADAKH

Office of the Chief Engineer PHE, I&FC Department Ladakh

Headquarter at Kagil.

No:-CE/PHE/I&FC/UTL/

Dated:- /04/2021.

The Regional Director,
Central Ground Water Board ,
Bantalab Jammu.

Subject:-Draft minites of 2nd meeting of UT Level Committee on "Ground Water Resource Estimation of LADAKH as on March 2020"held on 10-03-2021 for approval-reg.

Reference:-Your letter No:-TC-22/NWHR/GWRE/2020 Dated:-12-03-2021.

I am directed to convey the approval of draft minutes of 2nd meeting of UT level Committee for" Ground Water Resource Estimation of Ladakh as on 31 march 2020" held on 10-03-2021,with out any cutting and over writing (copy enclosed)

Yours Faithfully,

Chief Engineer,
PHE, I&FC Department,
Ladakh H/Q Kargil.

Copy to: -

1.Commissioner/Secretary PHE/IFC UT Ladakh for information and Necessary action, this is as discussed with him on 09-04-2021.

Draft minutes of 2nd meeting of UT Level Committee for Ground Water Resource Estimation for UT of Ladakh, as on 31st March, 2020 held on 10.03.2021

UT Level Committee for Ground Water Resource Estimation for UT of Ladakh, as on 31st March, 2020 held on 10.03.2021 at 03.00 PM through virtual mode under the chairmanship of Sh. Ajeet Kumar Sahu, The Secretary to Government, Jal Shakti Department, Leh, UT of Ladakh (Chairman, SLEC). The list of participants is given in Annexure-I.

At the outset of the meeting, Sh. Ashok Kumar, Regional Director (i/c), Central Ground Water Board, Jammu & Member Secretary welcomed the Chairman of SLEC, UT of Ladakh. The meeting was started with introduction of committee members and the agenda to be discussed during meeting and briefed about the Ground Water Resource Estimation Committee (GEC) 2015. Thereafter, with the permission of the Chair, proceedings started by way of presentation by Sh. M. L. Angurala, Scientist 'D', CGWB, Jammu who presented the results of GWRE as on March, 2020. Procedures and methodology adopted for ground water resource estimation of UT of Ladakh was explained in detail. The committee has in principle accepted the results of GWRE as on March, 2020.

After elaborate discussion with the committee members, the Chairman (SLEC) advised that in future, Ground Water Resource Estimation may be carried out on watershed boundary basis instead of administrative boundaries as the different valleys in Ladakh are hydrogeologically isolated units and have variable ground water withdrawals. This will help in assessing the ground water scenario separately of major towns of Ladakh and Leh in particular where Ground Water withdrawal is very high.

The Chairman (SLEC) emphasized that GWRE in Ladakh may be done in accordance with the agro-climatic conditions in Ladakh region as the region has negligible rainfall during monsoon season and sufficient snow fall in winter season. The water level in the month of November may be considered as pre monsoon and those in the May month be considered as post monsoon. He also emphasized that CGWB should conduct studies for sustainability of aquifer in Phyang valley and other parts of Ladakh region.

The Regional Director (i/c) & Members Secretary, assured the Committee that Ground Water Exploration studies along with Geophysical investigations will be carried out in Leh and Kargil Districts so as to decipher the aquifer geometry in valley portions of Ladakh region.

Meeting ended with the vote of thanks to the Chair.

****

Annexure-I

The list of the Officers attended the Meeting of UT Level Committee for Ground Water Resource Estimation for UT of Ladakh, as on 31st March, 2020 held on 10.03.2021 at 03.00 PM through virtual platform

A. List of Officers from Other Departments:

1. Sh. Ajeet Kumar Sahu, Administrative Secretary, PHE/IFC, Leh, Ladakh.
2. Sh. Fareed Ahmed Chaudhary, Chief Engineer, PHE, Leh, Ladakh.
3. Sh. Tahir Hussain, Director Rural Development, Leh, Ladakh.
4. Shri Moses Kunzang, Director Industries & Commerce, Leh, Ladakh.
5. Sh. Tashi Tsetan, Chief Agriculture officer represented Director Agriculture, Leh, Ladakh.
6. Sh. Tsewang Phunchok, Chief Horticulture officer, represented, Director Horticulture, Leh, Ladakh.

B. List of Officers from Central Ground Water Board, Jammu:

1. Sh. Ashok Kumar, Regional Director (i/c), CGWB, NWHR, Jammu, J&K.
2. Sh. M.L. Angurala, Scientist 'D', CGWB, NWHR, Jammu, J&K.
3. Sh. Vidya Nand Negi, Scientist 'D', CGWB, NWHR, Jammu, J&K.
4. Sh. B. Abhishek, Scientist 'B', CGWB, NWHR, Jammu, J&K.
5. Sh. Rayees Ahamad Pir, Assistant Hydrogeologist, CGWB, NWHR, Jammu, J&K.

LIST OF CONTRIBUTORS:

Department of Jal Shakti, Govt of Ladakh UT

1. Sh Fareed Ahmed Chaudhary, Chief Engineer, PHE/I&FC, Leh, UT of Ladakh.

Overall Guidance

1. Sh M L Angurala, Head Of Office, C.G.W.B, NWHR, Jammu.

Supervisor

1. Sh Vidya Nand Negi 'D', C.G.W.B, NWHR, Jammu.

Contributors

1. Sh. B. Abhishek, Scientist-B C.G.W.B, NWHR, Jammu.
2. Sh. Parvej Ahamad, Scientist-B C.G.W.B, NWHR, Jammu.