DYNAMIC GROUND WATER RESOURCES OF UT OF DAMAN, DIU AND DADRA & NAGAR HAVELI
2024

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

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भारत सरकार, /	U. T. Administration of
संघ प्रदेश दानह दमण एवं दीव प्रशासन, /	Dadra & Nagar Haveli and Daman & Diu,
कार्यपालक अभियंता का कार्यालय, /	Office of the Executive Engineer,
लोक निर्माण विभाग, /	Public Works Department,
निर्माण प्रभाग सं.१, /	Works Division No.I
मल्टी - ऑफिस कॉम्प्लेक्स, मोटी दमण, /	Multi Office Complex, Moti Daman.
दमण - ३९६ २२० /	Daman - 396 220

सं.लो.नि.वि/दमण/कार्य.अभि./प्रभाग/२०२२-२०२३/ 3040 दिनाक :- 17 /06/2022

ORDER

Pursuant to the directions of Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India and as stipulated in the National Water Policy, 2012 for periodic assessment of ground water resources have to be carried out for the territory of Dadra & Nagar Haveli and Daman & Diu for every year based on the approved latest ground water estimation methodology by Central Ground Water Board. The central Level Expert Group (CLEG) has been constituted on 08-02-2022 by Ministry of Jal Shakti, Govt. of India, which is a permanent expert group for overall supervision of assessment of ground water resources in the entire country annually for each water year (June to May). As advised by the Ministry of Jal Shakti, Govt. of India the State/UT level committee (SLC) has to be constituted on permanent basis for the Ground Water Resources (GWR) Assessment from 2022 onwards to coordinate and monitor the activities of GWR Assessments will be carried annually for each year. Competent Authority, Dadra & Nagar Haveli and Daman & Diu are please to constitute the Union Territory Level Committee for DNH & DD for assessment of ground water resources of Dadra Nagar Haveli and Daman & Diu with the following composition.

1.	Advisor to the Administrator, DNH & DD	Chairman
2.	Secretary (PWD), DNH & DD	Member
3.	Secretary, Industries, DNH & DD	Member
4.	Secretary, Urban Development , DNH & DD	Member
5.	Secretary, Panchayat, DNH & DD	Member
6.	Secretary, Agriculture, DNH & DD	Member
7.	Member Secretary, PCC, DNH & DD	Member
8.	Collector, DNH	Member
9.	Collector, Daman	Member
10.	Collector, Diu	Member
11.	General Manager, NABARD	Member
12.	Regional Director, CGWB	Member Secretary

The committee may co-opt any other member or special invitees, if necessary

2. Terms of Reference

The board terms of reference of the committee would be as follows

(I) To coordinate, monitor and ensure timely completion of assessment of annual ground water recharge of the territory of Dadra & Nagar Haveli and Daman & Diu through Central Ground Water Board and to estimate the status of utilization of the annual replenishable ground water resources in accordance with the Ground Water Resources Estimation Methodology-2015.

3. Time Frame: The Central Ground Water Board will submit its report for approval of the SLC and on approval; the report will be submitted to Government of India on or before the stipulated time frame.

4. Expenditure : Expenditure on account of TA/DA to official members of the committee will be met from the source from which they draw their salaries and that of non official members will be borne by EE, PWD(Irrigation), Dadra & Nagar Haveli, Silvassa and EE, PWD (WD-I), Daman, for Dadra & Nagar Haveli and Daman & Diu respectively.

This is issued with approval of Competent Authority vide Dairy No. 868153 dtd. 27/04/2022

17/6/2022

Joint Secretary,
Public Work Department, DNH & DD

DYNAMIC GROUND WATER RESOURCES OF UT of DAMAN, DIU AND DADRA & NAGAR HAVELI, 2024

AT A GLANCE

1.	Total Annual Ground Water Recharge	12335.91 Ham
2.	Annual Extractable Ground Water Resources	11577.14 Ham
3.	Annual Ground Water Extraction	16459.57 Ham
4.	Stage of Ground Water Extraction	142.17 %

CATEGORIZATION OF ASSESSMENT UNITS

(District)

Sl.No	Category	Number of Assessment Units		Recharge worthy Area		Annual Extractable Ground Water Resource	
		Number	%	In sq. km	%	(in BCM)	%
1	Safe						
2	Semi Critical						
3	Critical						
4	Over-Exploited	03	100	526.90	100	0.115	100
5	Saline						
	TOTAL	03	100	526.90	100	0.115	100

EXECUTIVE SUMMARY

The UT of Dadra and Nagar Haveli is covering an area 491 sq km and it is underlain by hard rock terrain (Deccan basalts). The thickness of vesicular units, ranges from 2 to 8 m. Ground water is developed by means of dug wells and dug cum bore wells. The sustainable yield of dug wells for 3 to 4 hours of pumping is 30 m^3/day. The transmissivity of shallow aquifer ranges from 5.5 to 305 m^2/day.

The UT of Diu is covering an area about 40 sq. km and is underlain by Alluvium and Milliolite soft rock formation. The UT of Daman is covering an area about 72 sq km area out of which 30 % is covered by alluvium and the rest is underlain by Basalt rocks. In UT of Daman & Diu, dug well as well as dug cum bore wells are common for irrigation and domestic use. The yields of open dug wells vary from less than 1 to 5 m^3/day, where as that of Dug cum Bore wells ranges from less than 2 to 10 m^3/day.

In UT of Daman &Diu:-The total Annual Ground Water Recharge has been assessed as 0.035 BCM and Annual Extractable Ground Water Resources as 0.033 BCM. The total current Annual Ground Water Extraction has been assessed as 0.057 BCM. Over all the Stage of Ground Water Extraction is 171% (Daman 158.77% and Diu 231.63%) and categorized as ‘Over Exploited’.

In UT of Dadra and Nagar Haveli: - The total Annual Ground Water Recharge has been assessed as 0.088 BCM and Annual Extractable Ground Water Resources as 0.082 BCM. The total current Annual Ground Water Extraction has been assessed as 0.107 BCM. Over all the Stage of Ground Water Extraction is 130.53% and categorized as ‘Over Exploited’.

Total recharge worthy area of the UT is 526.9 sq km , the entire area is under ‘Over-Exploited’. Total 115.77 MCM annual extractable ground water resources of the UT, 100% is under ‘Over-exploited’ categories of assessment units.

Chapter 1

1.1 PREVIOUS ASSESSMENTS

The first systematic methodology to assess the Ground Water Resources of the country was evolved by Ground Water Over-Exploitation Committee in 1979. The committee was constituted by Agriculture Refinance and Development Corporation (ARDC) and was headed by Chairman, CGWB with Members from State Ground Water Organizations and Financial Institutions. In 1982, Government of India constituted 'Ground Water Estimation Committee' (GEC) drawing Members from various States / Central organizations engaged in hydrogeological studies and groundwater development. The Committee submitted its recommendations in the year 1984 and suggested a methodology for assessment of dynamic groundwater resources, which is commonly referred to as GEC 1984. The Committee submitted its report in 1997 wherein a revised and elaborate methodology for resource assessment was suggested, which was referred as GEC 1997. In view of the limitations of ground water assessment in hard rock terrain, another Committee on Ground Water Estimation Methodology in Hard Rock Terrain was formed in 2001 to review the existing methodology for resource estimation in such formations. The Committee made certain suggestions on the criteria for categorization of Talukas to be adopted for the entire country irrespective of the terrain conditions. Based on GEC 1997, the dynamic ground water resources of India have been estimated for the entire country considering 2004, 2009, 2011 and 2013 as base years. The methodology underwent comprehensive revisions again in 2015 and a revised methodology, namely GEC 2015 methodology has been prescribed for ground water assessment. This methodology is being followed for ground water resource assessment carried out from 2017 onwards. Salient details of status of ground water resources and categorization of assessment units in 2017, 2020, 2022, 2023 and 2024 of the all UT are shown in Table 1.1, 1.2 and Table1.3 respectively.

Table 1.1 : Ground Water Resources Assessment 2017 to 2024, DNH District

Year of Assessment	2017	2020	2022	2023	2024
District	DNH	DNH	DNH	DNH	DNH
Assessment Unit Name	DNH	DNH	DNH	DNH	DNH
Recharge from Rainfall-MON	5737.20	4306.48	5702.39	5810.58	5876.08
Recharge from Other Sources-MON	137.57	661.93	661.93	661.93	661.93
Recharge from Rainfall-NM	330.00	329.73	329.73	329.73	329.73
Recharge from Other Sources-NM	656.82	1948.12	1948.12	1948.12	1948.12
Total Annual Ground Water (Ham) Recharge	6861.59	7246.26	8642.17	8750.36	8815.86
Total Natural Discharges (Ham)	343.00	494.21	574.08	579.49	582.76
Annual Extractable Ground Water Resource (Ham)	6518.59	6752.05	8068.09	8170.87	8233.10
Irrigation Use (Ham)	750.46	888.62	888.62	888.62	888.62
Industrial Use (Ham)	-	649.04	8565.98	8565.98	8565.98
Domestic Use (Ham)	1292.40	1568.14	1292.40	1292.40	1292.40
Total Extraction (Ham)	2042.86	3105.80	10747.00	10747.00	10747.00
Stage of Ground Water Extraction (%)	31.34	46.00	133.20	131.53	130.53
Categorization (OE/Critical/Semicritical/Safe)	safe	safe	over_exploited	over_exploited	over_exploited

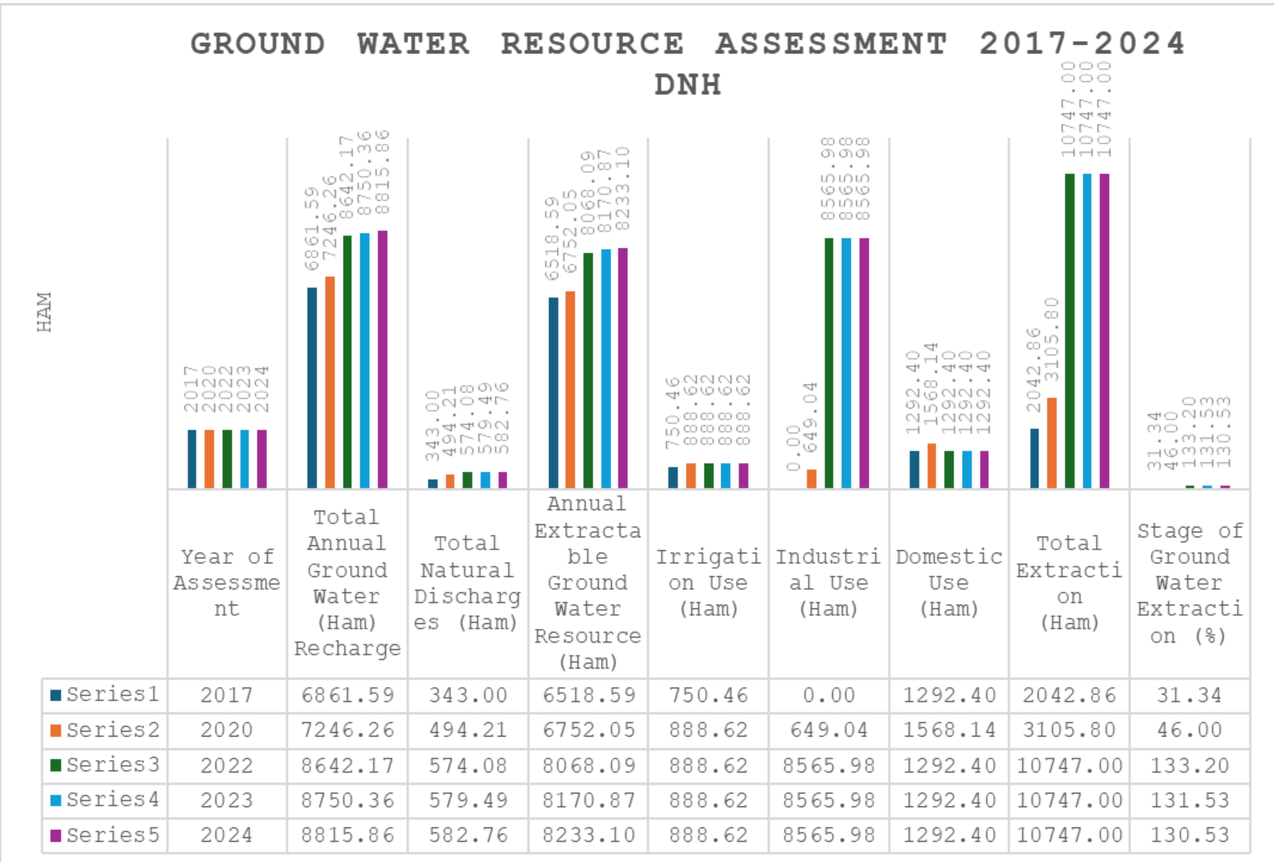


Table 1.2 Ground Water Resources Assessment 2017 to 2024 , Diu District

Year of Assessment	2017	2020	2022	2023	2024
District	DIU	DIU	DIU	DIU	DIU
Assessment Unit Name	DIU	DIU	DIU	DIU	DIU
Recharge from Rainfall-MON	412	208.15	547.86	549.48	545.42
Recharge from Other Sources-MON	20	14.13	14.13	14.13	14.13
Recharge from Rainfall-NM	0	0	0	0	0
Recharge from Other Sources-NM	39	23.09	23.09	23.09	23.09
Total Annual Ground Water (Ham) Recharge	471	245.37	585.08	586.7	582.64
Total Natural Discharges (Ham)	47	12.26	29.25	29.33	29.13
Annual Extractable Ground Water Resource (Ham)	424	233.11	555.83	557.37	553.51
Irrigation Use (Ham)	327	42.2	42.2	42.2	42.2
Industrial Use (Ham)	9	0	1239.89	1239.89	1239.89
Domestic Use (Ham)	50	0	0	0	0
Total Extraction (Ham)	386	42.2	1282.09	1282.09	1282.09
Stage of Ground Water Extraction (%)	91.03	18.10	230.66	230.02	231.63
Categorization (OE/Critical/Semicritical/Safe)	critical	safe	Over-exploited	Over-exploited	Over-exploited

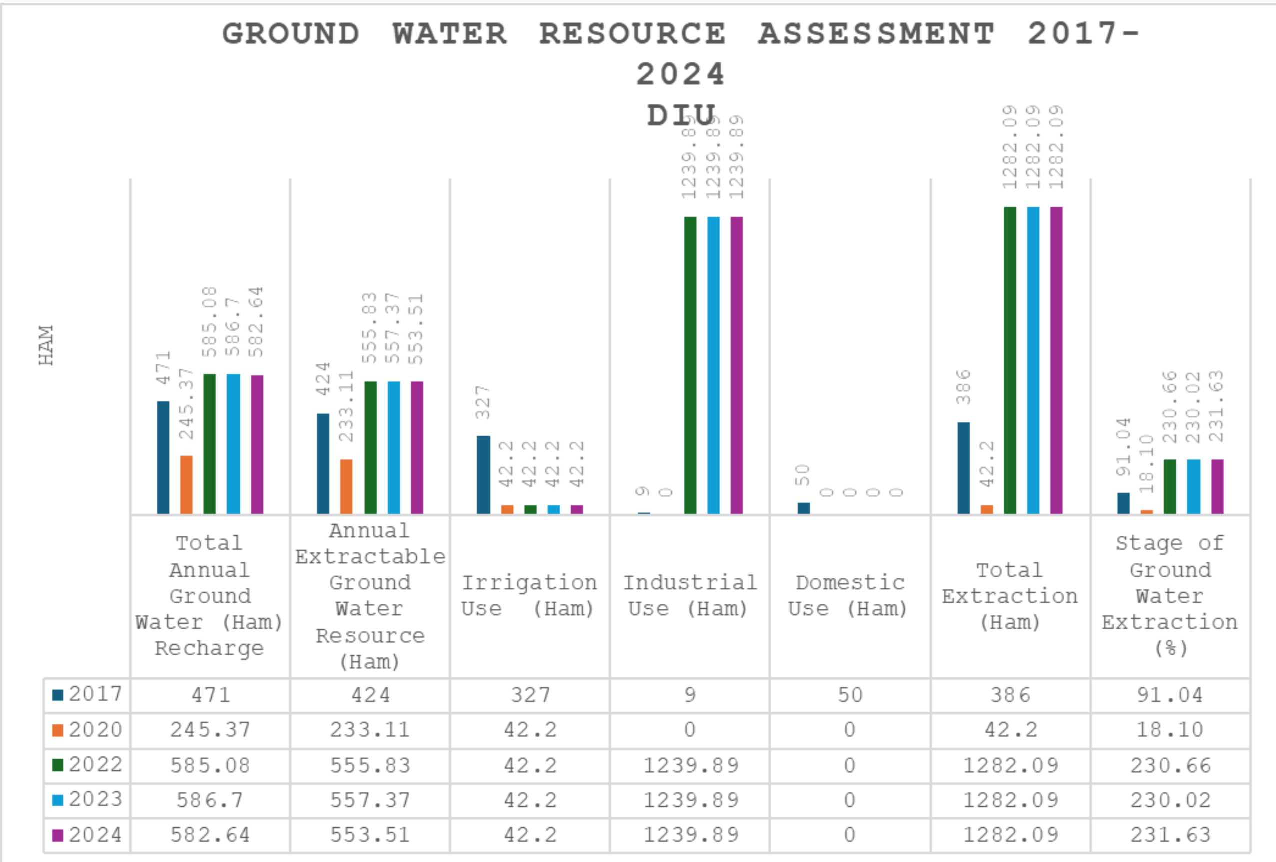
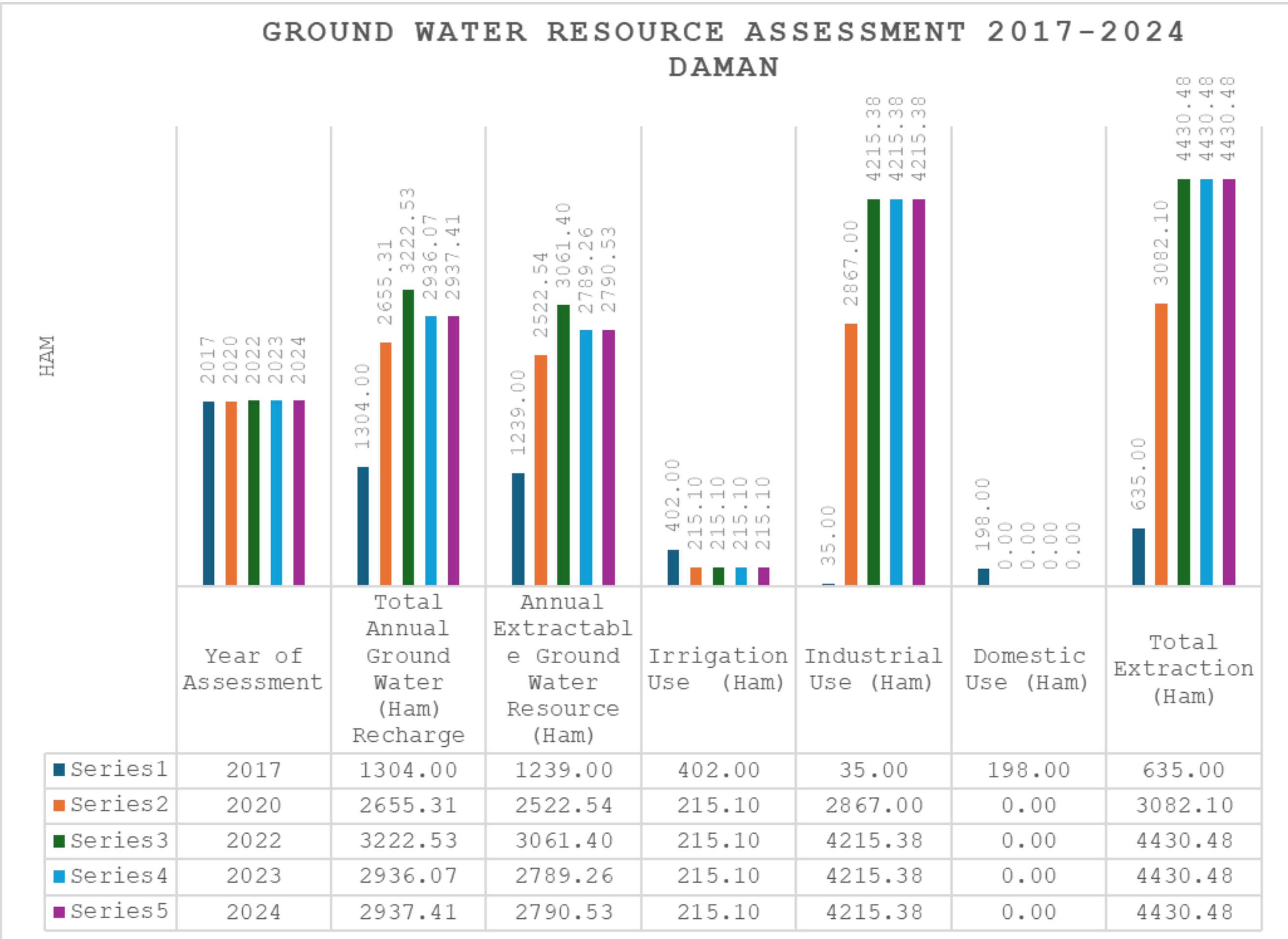


Table.1.3 Ground Water Resources Assessment 2017 to 2024, Daman District

Year of Assessment	2017	2020	2022	2023	2024
District	DAMAN	DAMAN	DAMAN	DAMAN	DAMAN
Assessment Unit Name	DAMAN	DAMAN	DAMAN	DAMAN	DAMAN
Recharge from Rainfall-MON	1172.00	2551.89	3109.41	2822.95	2824.29
Recharge from Other Sources-MON	38.00	35.50	41.21	41.21	41.21
Recharge from Rainfall-NM	0.00	0.00	0.00	0.00	0.00
Recharge from Other Sources-NM	94.00	67.92	71.91	71.91	71.91
Total Annual Ground Water (Ham) Recharge	1304.00	2655.31	3222.53	2936.07	2937.41
Total Natural Discharges (Ham)	65.00	132.77	161.13	146.81	146.88
Annual Extractable Ground Water Resource (Ham)	1239.00	2522.54	3061.40	2789.26	2790.53
Irrigation Use (Ham)	402.00	215.10	215.10	215.10	215.10
Industrial Use (Ham)	35.00	2867.00	4215.38	4215.38	4215.38
Domestic Use (Ham)	198.00	0.00	0.00	0.00	0.00
Total Extraction (Ham)	635.00	3082.10	4430.48	4430.48	4430.48
Stage of Ground Water Extraction (%)	51.25	122.18	144.72	158.84	158.77
Categorization (OE/Critical/Semicritical/Safe)	safe	over_exploited	over_exploited	over_exploited	over_exploited



1.2 INTRODUCTION

Daman district is situated between North latitudes 20°22’7.03”N & 20°28’28.4”N and East longitudes 72°48’7.12”E & 72°54’11.9”E and falls in Survey of India toposheet No. 46 D/15. It covers an area of 72 sq. km. Its length measures 11 km from extreme north to south and the width measures 8 km. from east to west. The UT of Daman is bounded on the north, east and south by Valsad district of Gujarat state and west by Arabian Sea (Fig. 1).

Diu distrcit is a completely isolated island from mainland Gujarat by east-west extending marshy low land which remains covered by the tidal waters of the Arabian sea. Diu is situated between North latitudes 20°41’53.66”N & 20°44’47.89”N and East longitudes 70°52’31.02”E & 71°0’51.25”E and falls in Survey of India Toposheet No. 41 L/14. It covers an area of 40 sq. km with 19.2 km length and width varying from 1 to 2.5 km. The UT of Diu is bounded on the east, west and north side by Gir Somnath district, whereas Southern boundary is the Arabian Sea with its partly rocky and partly sandy shore (Fig. 1).

UT of Dadra and Nagar Haveli is composed of two separate geographical entities: Nagar Haveli, wedged in between Maharashtra and Gujarat states 1 KM to the north-west, and the smaller enclave of Dadra, which is surrounded by Gujarat. Silvassa is the administrative headquarters of DNH. It covers an area of 491 km^2. Its population density is 698. Though landlocked between Gujarat to the north and Maharashtra to the south, it is close to the western coast of India (between 20°0′ and 20°25′ N latitude and between 72°50′ and 73°15′ E longitude).

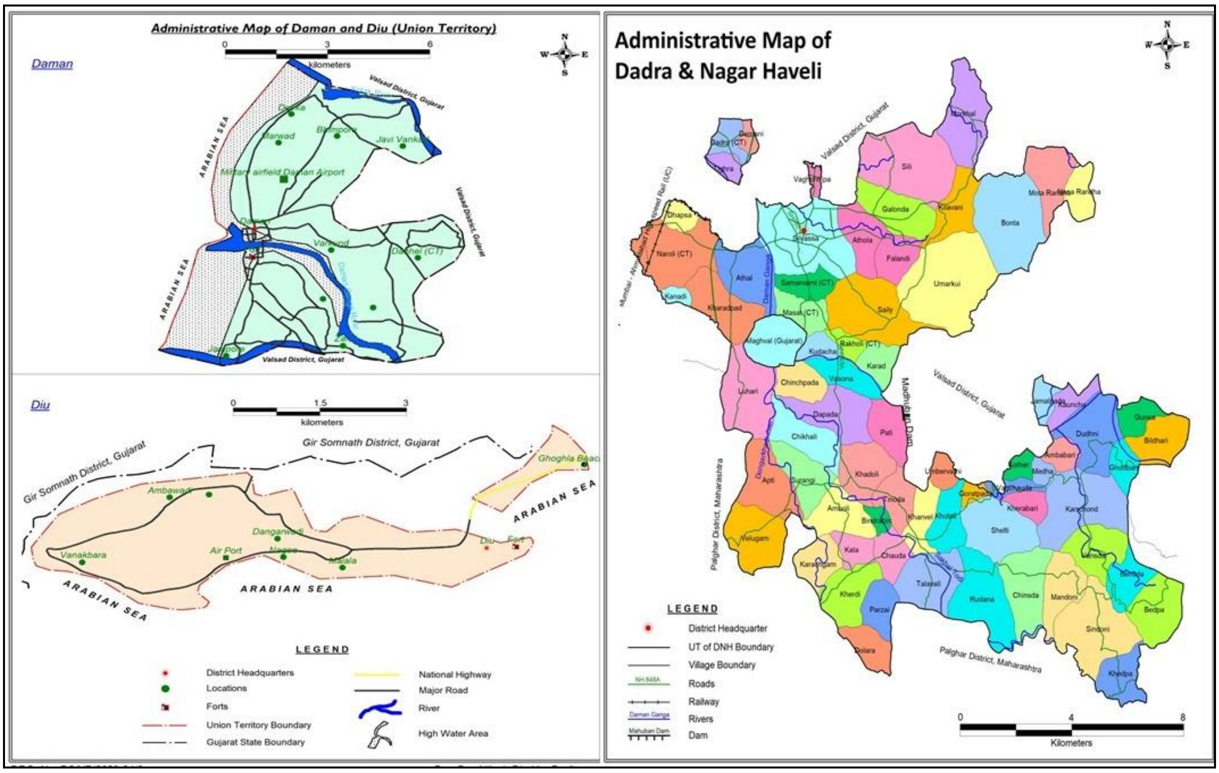


Figure 1- Administrative Map of Daman, Diu and DNH

1.3 GEOMORPHOLOGY

DAMAN:

It has a gently undulating topography with a few isolated hillocks ranging in height from 34 to 49m amsl with the exception of 111 m high hill occupying an area of more than a Km^2 towards east of Delwada village. The general topographic gradient is towards west-northwest.

The soils in the area can be divided into two groups based on their origin. The soils all along the coast and the banks of the creek are alluvial soils whereas in rest of the area the soils are derived from the weathering of basaltic rocks. The coastal soil, as they are deposited in saline water, is saline and alkaline with almost uniform texture which is clayey loam to silty loam. The soils are dark grey to black in colour. Both pH and Electrical conductivity values are extremely high. These soils are difficult to reclaim due to higher content, low permeability, high water table and high salinity.

Depending upon the degree of weathering, the basaltic soils show wide variation in texture. The first stage of weathering of basalts gives rise to light soil comprising pieces of weathered basalt (locally known as maroom). The depth of such soil varies from few cm to 50 cm. The colour of the soil is dark yellowish brown in plateau, and around the hillocks, whereas the colour is brownish black to black cotton in the flat valleys. The texture of the soil is medium to fine textured. They are non-calcareous with moderate water holding capacity.

DIU:

There is a central high land made up of sand dune and sloping in all the direction and the reduced level comes to around 2 m agl along the coast.

Up to almost a kilometre from the coast, the soils are saline and alkaline with higher percentage of silt. These are formed due to degeneration of coastal soils by salinity ingress. These soils slowly grade into yellowish brown calcareous soils which contain admixture of medium to coarse grained material comprising Miliolite shell pieces. They range in thickness from 0.3 to 1 m. in low lying areas, accumulation of organic material coupled with intense weathering, have given rise to black cotton soil covers varying from few cm to nearly a metre in thickness. The blown sand deposits, on the central high land, are essentially weathered products of the friable Miliolitic limestone and are thus highly calcareous.

DADRA & NAGAR HAVELI:

Geomorphologically, the UT of DNH forms part of Deccan Plateau. The UT of DNH is divided into three units i.e., Residual Plateaus, Denudational Slopes and Valley Plains.

Residual Plateaus: These are flat-topped crests surrounded by steep scarps. These residual plateaus occur in the western fringe, the south-eastern part and in the isolated patches in the north eastern part of the Territory. The elevation in this category ranges between 100-300 m amsl the elevation more than 200 m amsl is seen in north eastern and south-eastern part of the Territory.

Denudational Slopes: The major area under this category lies almost in the eastern part in north south alignment in dissected form ranging roughly between 50 and 100 m above MSL.

Valley Plains: The valley plains occupying an area of 184 sq.km. and forms the flat topography with gentle slope of SE-NW forming the Damanganga River and its tributaries and it ranges in elevation below 50 m above m amsl. It comprises of weathered rock fragments and soils. The rock fragments are various sizes and mixed with soils.

1.4 DRAINAGE

DAMAN & DIU:

The river Daman Ganga passing through the middle of Daman divided it in to two parts namely Moti Daman and Nani Daman. The altitude is 12 m amsl. The Kolak river flows along the northern boundary and the Kalu nadi forms the southern boundary. These three rivers flowing almost parallel to each other enter Daman from south east and follow almost westerly course.

Natural drainage system in Diu is conspicuously absent, with marshy land dominating the northern coast and the southern coast forming the Arabian Sea being partly rocky and sandy.

DADRA & NAGAR HAVELI:

The UT of Dadra and Nagar Haveli lies in the middle of the undulating watershed of the Daman Ganga River, which flows through Nagar Haveli and later forms the short southern border of Dadra. The towns of Dadra and Silvassa lie on the north bank of the river. The Western Ghats range rises to the east, and the foothills of the range occupy the eastern portion of the UT. While the UT is landlocked, the Arabian Sea is just to its west, and can be reached via the state of Gujarat. The major river of the area is Damanganga which flows in SE- NW direction. The major tributaries of Damanganga are Dudhninadi,Sakartondnadi, Dongarkhadinadi, Pipriya and Ratinadi.

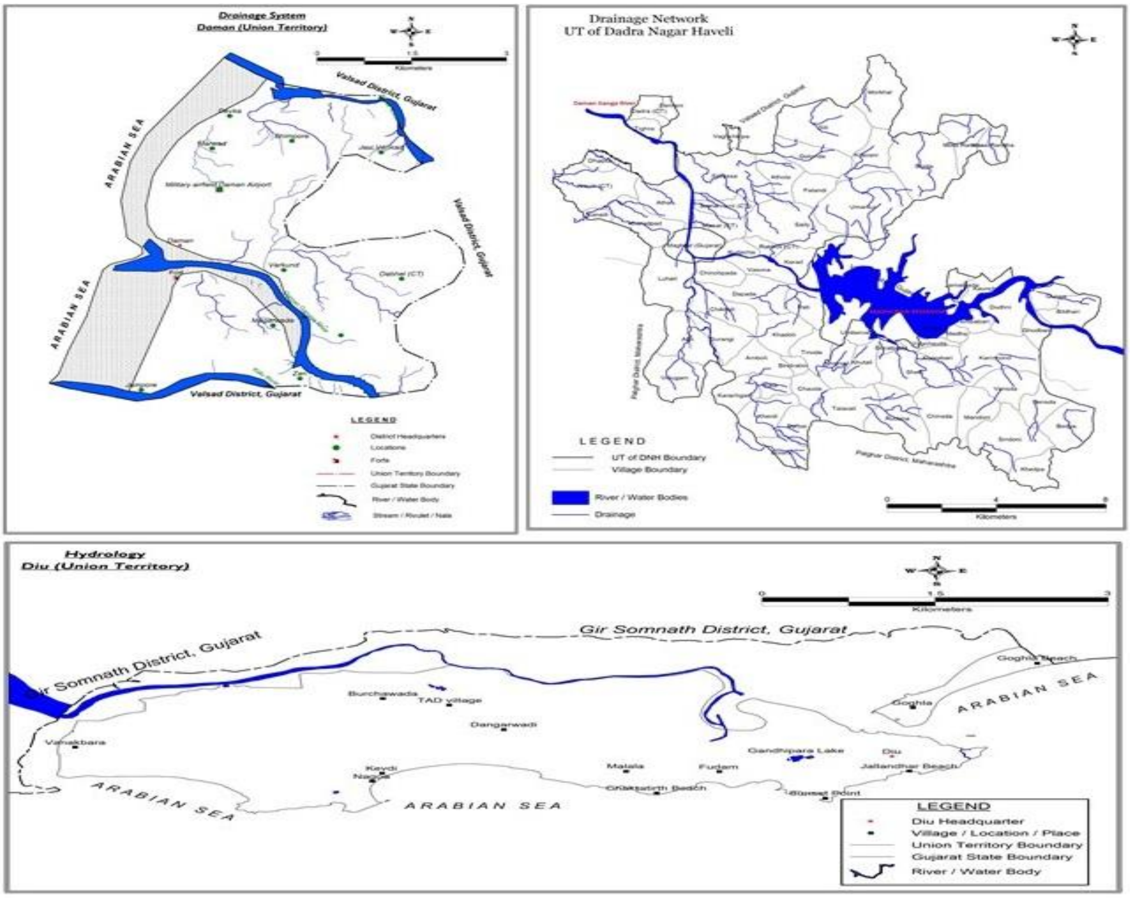


Figure 2- Drainage Map of Daman, Diu and DNH

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1.5 RAINFALL

DAMAN:

The rainfall occurs during the southwest monsoon, starting from June and extending up to October. The rainfall is inconsistent, with average annual rainfall 1985 mm. Long term monthly means of annual rainfall distribution shows that over 95 % of the rainfall occurs from mid-June to mid-September due to southwest monsoon. July is the rainiest month with nearly 900 mm of average rainfall. The rainfall characteristics have a strong impact on the groundwater level and quality of UT of Daman. The year wise rainfall are given in table no.1.4.

DIU:

The rainfall occurs during the southwest monsoon, starting from June and extending up to October. The rainfall is inconsistent, with average annual rainfall 598.60mm in 34 rainy days. The long-term average annual rainfall is 664.04 mm. Long term monthly means of annual rainfall distribution shows that over 90 % of the rainfall occur from mid-June to mid-September due to southwest monsoon and associated intense low-pressure system. The rainfall characteristics have a strong impact on the groundwater level and quality.

DADRA & NAGAR HAVELI:

The analysis of long-term rainfall data pertaining to the period 2014-2023 has also been carried out (**Annexure-2**) and the probability of occurrence of normal annual rainfall over the UT of DNH has been studied. It was observed that the distribution of rainfall is more or less uniform over the area. The rains usually start in the second week of June and last till the end of September.

Table 1.4- Average Rainfall (mm) in Daman, Diu and DNH

Sl No.	Year	Daman		Diu		DNH	
		Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon
1	2014-2015	2059	0	909	0	1937	342
2	2015-2016	1333	0	1031	0	1346	238
3	2016-2017	2113	0	886	0	1973	348
4	2017-2018	1973	0	939	0	3081	544
5	2018-2019	1834	0	950	0	1782	314
6	2019-2020	2962	0	1100	0	2684	474
7	2020-2021	1676	0	1136	0	2202	474
8	2021-2022	2382	0	953	0	2382	474
9	2022-2023	3100	0	982	0	3100	474
10	2023-2024	2398	0	1070	0	2398	410

1.6 GEOLOGY

DAMAN:

Geologically Daman district is a northern extension of Deccan Plateau of Central India, belonging to late Cretaceous – early Eocene age and here, it is followed by Quaternary sediments. The stratigraphy sequence of Daman district is presented in Table-1.5.

Table 1.5- STRATIGRAPHIC SEQUENCE OF DAMAN DISTRICT

Geological Age	Formation	Group	Lithology
Holocene	Mahuva Formation		Younger tidal formation, spit / bar and shoal deposit
	Akhaj Formation		Coastal dune deposit
	Rann Clay Formation		Older tidal flat deposit
	Katpur Formation		Flood plain deposit
Upper Cretaceous to Eocene	Extrusive	Deccan	Granophyre and other basic dykes, sills & plugs
	Intrusive	Volcanic	Basalt & Dacite

DIU:

The area comprises Miliolite limestone of Pleistocene to Recent age and of about 50 m thick. It is a highly porous limestone which is friable except for the one or two layers near the ground surface, where the calcification of the limestone due to calcium carbonate solution has given rise to hard and compact crust. The Miliolite limestone is of high grade with very little contents of magnesium. Solution activity has resulted in formation of caverns of varying dimensions. This karstic activity is more predominant in the zone of water level fluctuation and near the lower contact with the underlying clay formations. The limestones exhibits strike which is roughly parallel to sea and the dips are undulating like typical sand-dune deposits.

Miliolite limestones are underlain by Gaj formations of Miocene age. The Gaj formations comprise upper yellowish white clays underlain by interbedded marls, calcareous sandstones and grits, impure limestones and clays. The Gaj formation is found to be extending down to the explored depths of 200m. The base of Gaj Formation rests over the Deccan Trap Basalt.

The generalized geological succession in the area is given below in Table No- 1.6.

Table 1.6- STRATIGRAPHIC SEQUENCE OF DIU DISTRICT

Age	Formation	Lithology	Max. thickness/ Remarks
Recent to Pleistocene	Coastal Alluvium & Miliolite limestone	Sand, clays, Miliolite-limestone	40-50 m
Miocene (Tertiary)	Gaj beds	Clay, Marl, calc. sandstone, limestone etc.	Not Exposed, +200 m
Upper Cretaceous to Eocene	Deccan Trap	Basaltic lava	Not exposed

DADRA & NAGAR HAVELI:

The area exposes a thick succession of basaltic lava flows of cretaceous to Eocene age. The flows have been intruded by a number of basic and intermediate dykes. A major Trachyte-Rhyolite acidic complex in the western part of the area is quite conspicuous. The flows are intruded by dykes of dolerite and basalt. The intrusions have north-south trends and are quite closely spaced. The area is occupied by 16 basaltic flows within 390m thick lava pile between elevation of 40 m and 435 m amsl. Nine out of 16 basaltic lava flows are of 'aa' type and seven are compound pahoehoe in nature.

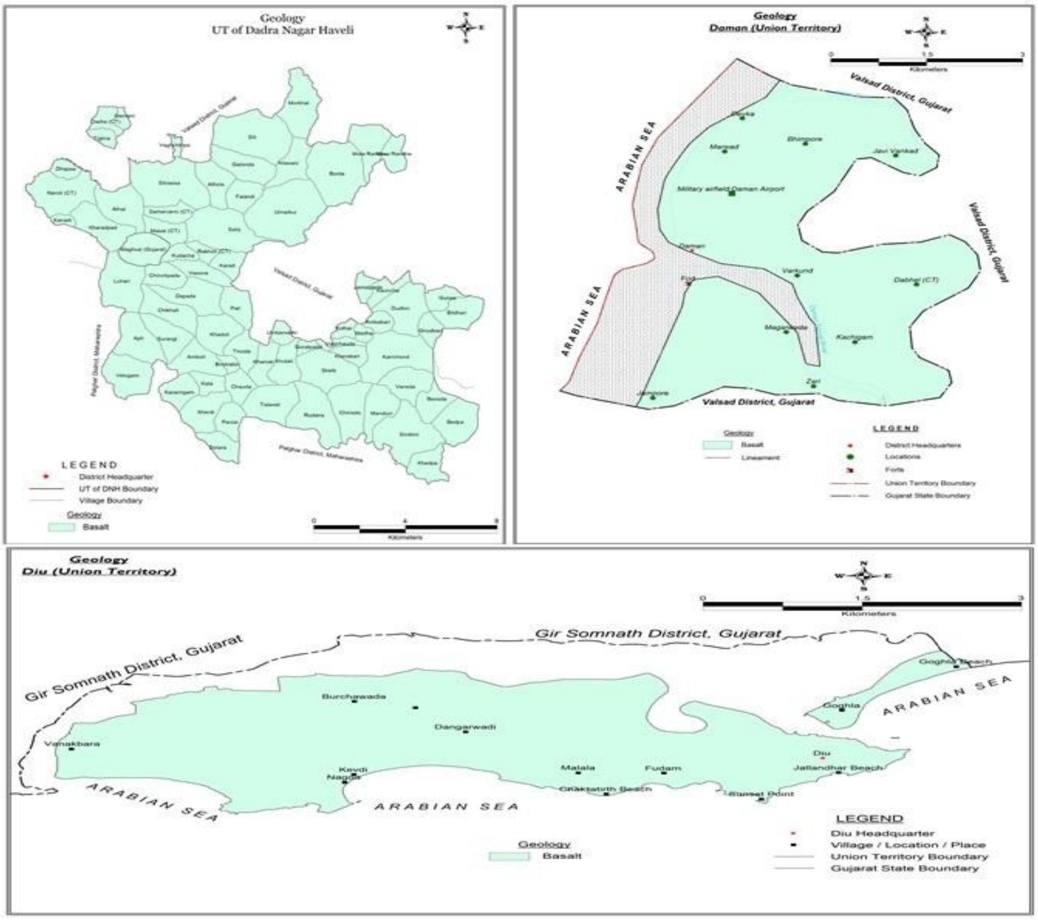

Figure 3- Geological Map of Daman, Diu and DNH

1.7 HYDROGEOLOGY

DAMAN:

Basalt is the main basement rock which occurs at variable depths in most parts of Moti Daman and also exposed at surface in the north west part of Daman namely in Marwad, Devka, Kadiya. Basalt sheet rocks are exposed in river beds of Daman Ganga, Kalu and kolak rivers bordering UT of Daman. Alluvial deposits are found overlying the basalts, all along Moti Daman area and also in Dabhel and Kachigam areas having depth of 12 to 40m bgl. Alluvium deposits are river terrace type along the banks of river Daman Ganga.

The basalt occurs in the form of flows comprising massive and compact basalt in the bottom and gradually passes into vesicular basalt at the top. The basalts vary in colour from dark green to pink and show different sets of joints. All the joint systems are restricted to the individual flow seldom cutting across other flows. The surface weathering is characterized by spheroidal weathering. The major Aquifer system of Daman district is represented in below Figure No.4

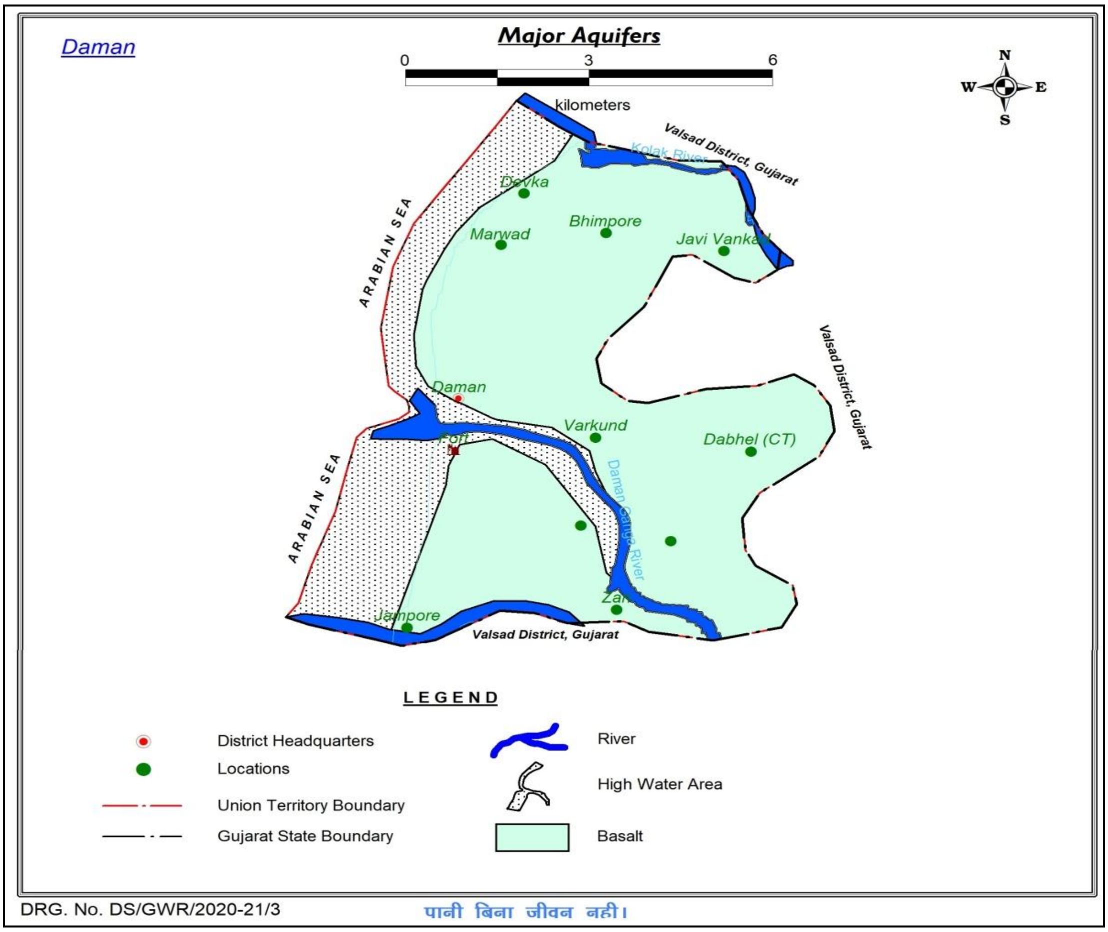

Figure 4- Hydrogeology Map of Daman

DIU:

Groundwater occurs under water table condition in the Miliolite limestone. The depth to water table varies from 12 m bgl in the central high land to 3 m bgl in the area up to 1 km inland from the high tide water line. Close to salt pans or sea, the water levels are almost same as high water line levels. This suggests that the central high land is the main ground water recharge area and sub-surface flow of ground water is from the central high land to the coastal area. The seasonal fluctuation in the water table level is 2 to 5 m in the central high land but along the coastal strip, the seasonal water level fluctuations are insignificant. The yields of wells are very high (50 m^3 to 240 m^3/ day) and drawdown ranging from 0.5 to 1.25 m.

The groundwater occurs in inter-bedded calcareous sandstones, grits and arenaceous limestones of the deeper Gaj formation. Ground water is in confined condition in this formation with piezometric levels varying from 1.5 m to 3.0 m bgl. The quality of the water is saline in the upper Gaj formations, which is inherent as the deposition of Gaj formation was in marine condition. The intercalated marls and clay formations, which restrict the circulation of ground water, cause further deterioration in quality.

Pumping tests in two Dugwells (Large Diameter wells) were carried out by A.Ahmed (1980). The results of the short duration pumping test conducted at Sarwari, near airfield and Phophrona village revealed the specific capacities of the dugwells were (as determined by Slitcher's formula) 566.39 lpm/m and 31 lpm/m respectively. The rates of infiltration were 322.8 lpm and 40.92 lpm respectively (After Ahmed, 1980). The major Aquifer system of Diu District is represented in below Figure No.5

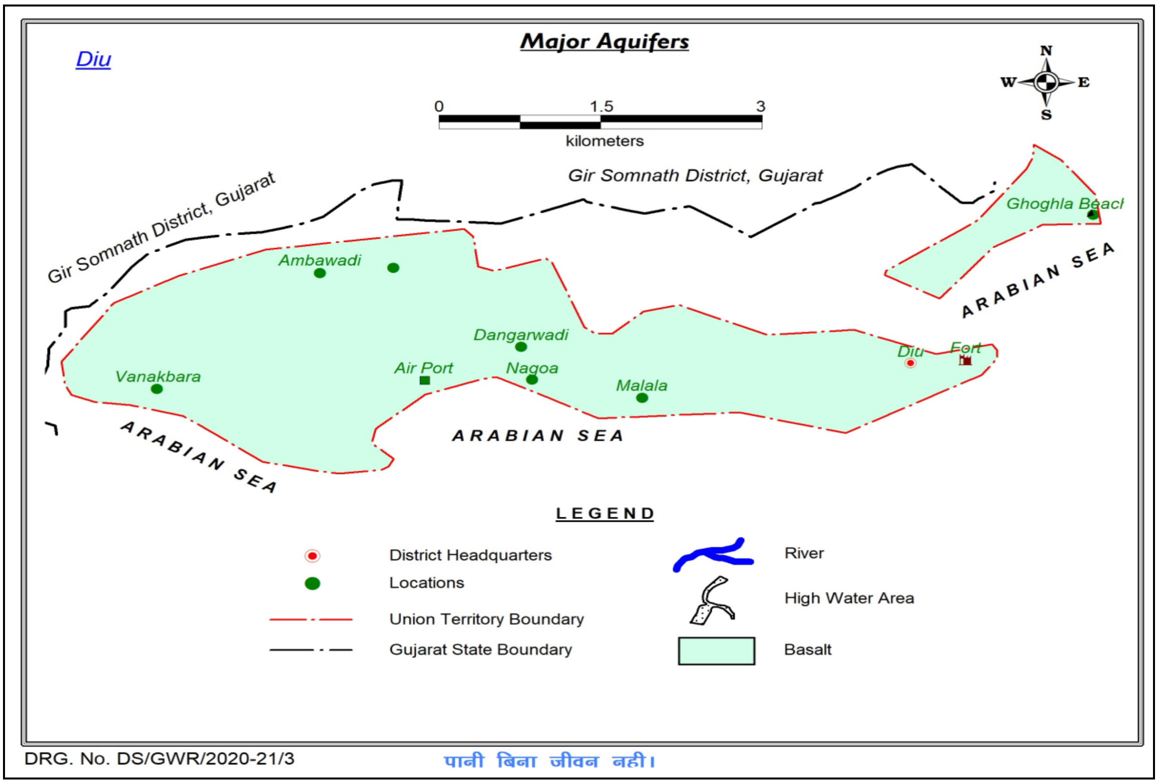

Figure 5- Hydrogeology Map of Diu

DADRA & NAGAR HAVELI:

Hydrogeology is concerned primarily with mode of occurrence, distribution, movement and chemistry of water occurring in the subsurface in relation to the geological environment.

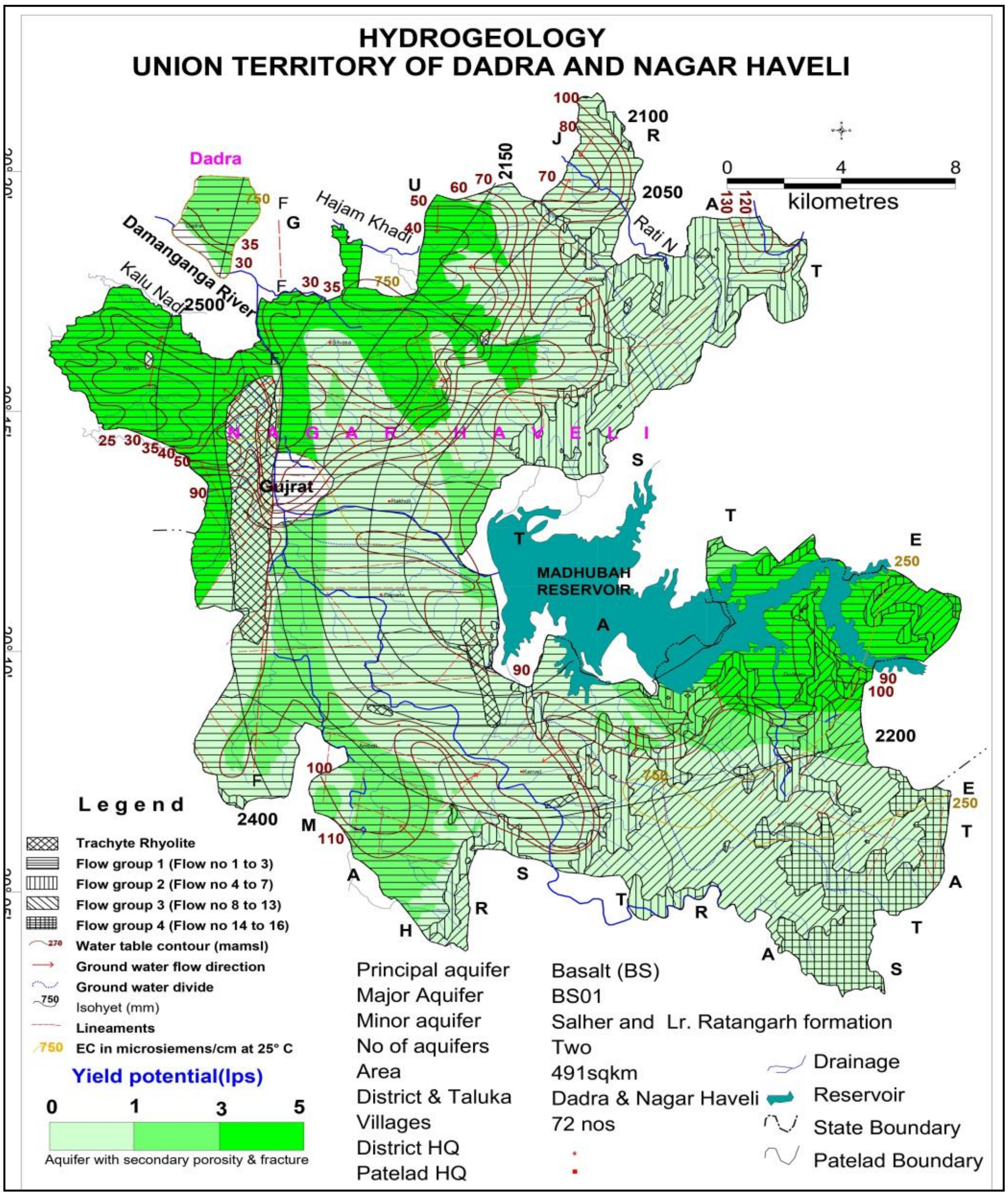

Figure 6- Hydrogeological Map of DNH

The occurrence and movement of water in the subsurface is broadly governed by geological frameworks i.e., nature of rock formations including their porosity (primary and secondary) and permeability. The principal aquifer in the area is Basalt, where the occurrence and movement of ground water primarily depends on the degree of interconnection of secondary pores/voids developed by fracturing and weathering. The hydrogeological map of area is prepared and presented in Fig.6.

The basaltic lava flows are massive and fine grained with negligible primary porosity and transmissivity. The area occurs in the vicinity of western coast, which have witnessed many tectonic disturbances. These have caused development of joints and fractures in the basaltic strata. Also weathered zones of about 10-20 m thickness have developed in plains and depressions. Thus the weathered, jointed and fractured zones of vesicular and massive units of a flow constitute the main water bearing horizons. However, these zones are not continuous and uniformly developed laterally or vertically and this factor plays an important role in the success and failure of wells in the area.

Groundwater occurs in unconfined state in shallow aquifer tapped by dugwells of 10 to 30 m depth, water levels are ranging from 1.20 – 15.00 m bgl and yield varies from 10 to 100 m^3/day. The deeper aquifer is also present and it ranges from 30-90 m bgl, whereas the water level ranges from 8 to 55 m bgl. The groundwater development is mostly through dugwells rather than borewells.

Limited yields of upto 1 lps are observed in a horse shoe shaped patch occurring along north, central and southern parts, whereas moderate yields of 1 to 3 lps are being observed in limited areas in western parts and high yields of 3 to 5 lps are present in north western and south eastern parts of the UT of DNH.

1.8 GROUND WATER LEVEL SCENARIO IN THE UTs

1.8.1 Depth to Water Level (May 2023)

In **Daman**, 37.5% of the monitoring wells show water levels ranging from 2 to 5 meters bgl, and 5 to 10 meters bgl range. While 12.5% fall within the 10-20 m bgl. Total of eight wells were analyzed for the dynamic groundwater assessment of the UT, with water levels ranging from 6.07 to 7.85 meters bgl.

In **Diu**, 60% of the monitoring wells show water levels ranging from 5 to 10 meters bgl, while 40% fall within the 5 to 10 meters bgl range. Total 5nos of well analyzed for the estimation of dynamic groundwater assessment of the UT of Diu falls in the water levels ranges 5.08 to 6.15 m bgl.

In **Dadra and Nagar Haveli**, 38.5% of the monitoring wells show water levels ranging from 5 to 10 meters bgl, while 40% fall within the 5 to 10 meters bgl range and 15.4% stations fall within 0-2 mbgl and 10-20 mbgl.

Total 13 nos of well analyzed for the estimation of dynamic ground water assessment of the UT of Dadar Nagar Haveli. The details of groundwater regime monitoring station are given in table no.1.7.

Table 1.7: Depth to Water Level - May 2023

Sr. No.	District Name	No of well analyzed	DTWL, mbgl		No. of wells in different depth range (mbgl)					
			Min	Max	0 to 2	2 to 5	5 to 10	10 to 20	20 to 40	> 40
1	Daman	8	3.3	9.21	1	3	3	1	0	**0**
					12.5%	37.5%	37.5%	12.5%	0.0%	**0.0%**
2	Diu	5	3.81	7.33	0	2	3	0	0	**0**
					0.0%	40.0%	60.0%	0.0%	0.0%	**0.0%**
3	Dadra and Nagar Haveli	13	2.7	12.6	2	4	5	2	0	**0**
					15.4%	30.8%	38.5%	15.4%	0.0%	**0.0%**
	UT of Daman and Diu & Dadra and Nagar Haveli	**26**	**3.30**	**9.21**	3	9	11	3	0	**0**
					11.5%	**34.6%**	**42.3%**	**11.5%**	**0.0%**	**0.0%**

1.8.2 Depth to Water Level (November 2023)

In **Daman**, 53.8% of the monitoring wells show water levels ranging from 2 to 5 meters bgl, While 38.5% fall within the 0-2 m bgl. A total of eight wells were analyzed for the dynamic groundwater assessment of the UT, with water levels ranging from 2.61 to 3.86 meters bgl.

In **Diu**, 66.7% of the monitoring wells show water levels ranging from 5 to 10 meters bgl, while 33% fall within the 5 to 10 meters bgl range. Total 5nos of well analyzed for the estimation of dynamic ground water assessment of the UT of Diu falls in the water levels ranges 4.14 to 5.11 m bgl.

In **Dadra and Nagar Haveli**, 64.7% of the monitoring wells show water levels ranging from 2 to 5 meters bgl, while 17.6% fall within the ranges from 5 to 10 and 0-2 m bgl..
Total 13 nos of well analyzed for the estimation of dynamic ground water assessment of the UT of Dadar Nagar Haveli.The details of groundwater regime monitoring station are given in table no.1.8.

Table 1.8: Depth to Water Level - November 2023

Sr. No.	District Name	No of well analyz e d	DTWL, mbgl		No. of wells in different depth range (mbgl)					
			Min	Max	0 to 2	2 to 5	5 to 10	10 to 20	20 to 40	> 40
1	Daman	13	1.15	6.13	5	7	1	0	0	**0**
					38.5 %	53.8 %	7.7%	0.0%	0.0%	**0.0%**
2	Diu	6	2.75	6.6	0	2	4	0	0	**0**
					0.0%	33.3 %	66.7%	0.0%	0.0%	**0.0%**
3	Dadra and Nagar Haveli	17	1.53	9.37	3	11	3	0	0	**0**
					17.6 %	64.7 %	17.6%	0.0%	0.0%	**0.0%**
	UT of Daman and Diu &Dadra and Nagar Haveli			**9.37**	8	20	8	0	0	**0**
		36	**1.15**		**22.2 %**	**55.6 %**	**22.2 %**	**0.0%**	**0.0%**	**0.0 %**

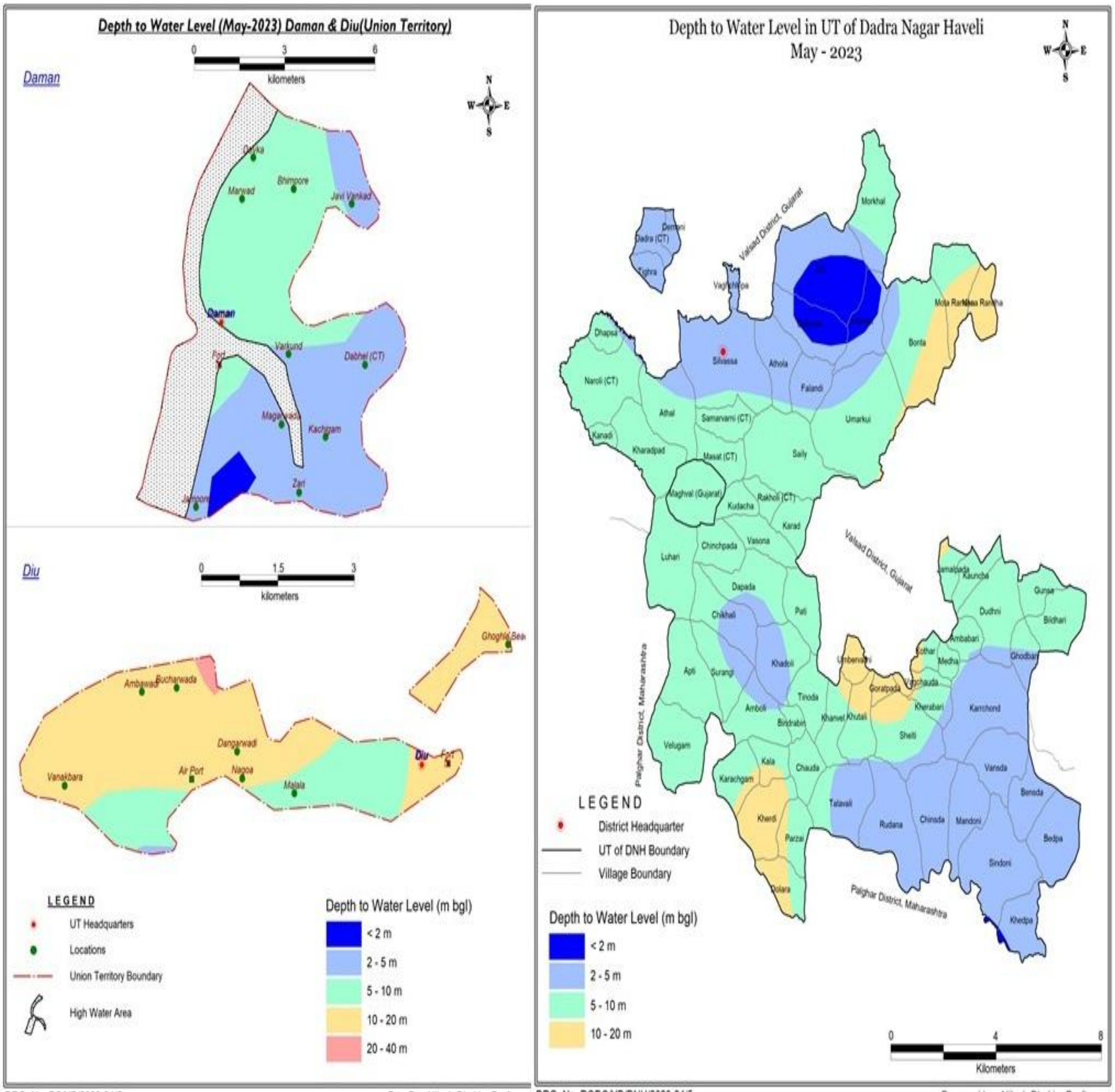

Figure 7- Depth to Water Level Pre-Monsoon (May 2023)

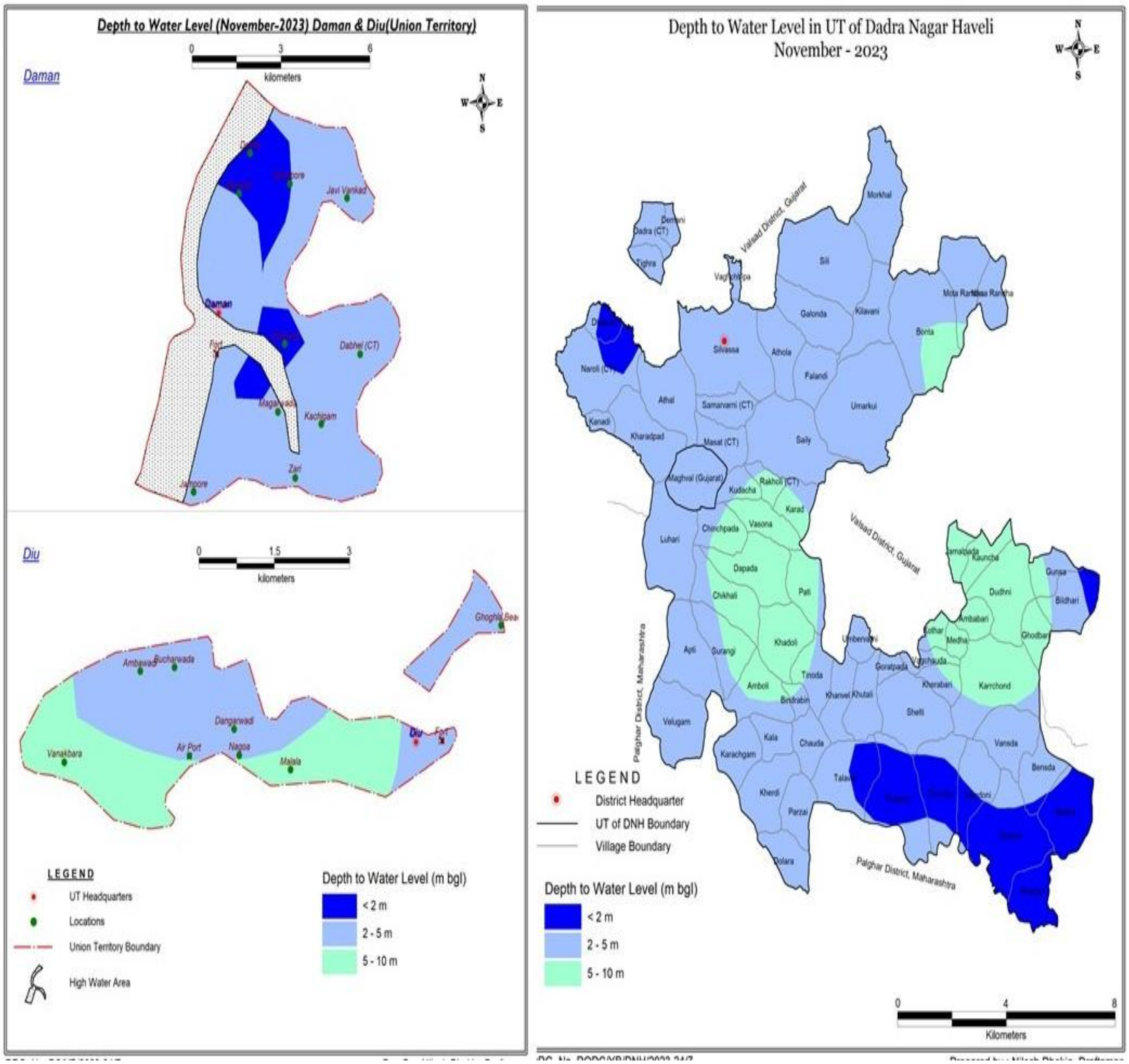

Figure 8- Depth to Water Level Post-Monsoon (November 2023)

Chapter 2

GROUND WATER RESOURCE ESTIMATION METHODOLOGY

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

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

2.1 GROUND WATER ASSESSMENT OF UNCONFINED AQUIFER

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

i. Assessment of Annually Replenishable or Dynamic Ground Water Resources

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

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

Equation (1) can be further elaborated as –

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

Where,

ΔS - Change is storage
R_{RF} - Rainfall recharge
R_{STR} - Recharge from stream channels
R_C - Recharge from canals
R_{SWI} - Recharge from surface water irrigation
R_{GWI} - Recharge from ground water irrigation
R_{TP} - Recharge from Tanks & Ponds
R_{WCS} - Recharge from water conservation structures
VF - Vertical flow across the aquifer system
LF - Lateral flow along the aquifer system (through flow)
GE - Ground Water Extraction

T - Transpiration
E - Evaporation
B - Base flow

Due to lack of data for all the components in most of the assessment units, at present the water budget has been assessed based on major components only, taking into consideration certain reasonable assumptions. The estimation has been carried out using lumped parameter estimation approach keeping in mind that data from many more sources if available may be used for refining the assessment.

1. Rainfall Recharge

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

a. Ground Water Level Fluctuation Method

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

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

Where,

ΔS - Change is storage
R_{RF} - Rainfall recharge
R_{STR} - Recharge from stream channels
R_{SWI} - Recharge from surface water irrigation
R_{GWI} - Recharge from ground water irrigation
R_{TP} - Recharge from Tanks& Ponds
R_{WCS} - Recharge from water conservation structures
VF - Vertical flow across the aquifer system
LF - Lateral flow along the aquifer system (through flow)
GE - Ground water extraction
T - Transpiration
E - Evaporation
B - Base flow

Whereas the water balance equation in command area have another term i.e., Recharge due to canals (R_C) and the equation is as follows:

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

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

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

Where,

ΔS - Change is storage
Δh - rise in water level in the monsoon season

A - Area for computation of recharge

S_Y - Specific Yield

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

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

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

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

Normalization of Rainfall Recharge

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

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

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

Where,

R = Rainfall recharge during monsoon season

r = Monsoon season rainfall

a = a constant

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

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

Where,

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

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

r(normal) - Normal monsoon season rainfall

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

N - No. of years for which data is available

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

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

Where,

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

r(normal) - Normal monsoon season rainfall

a and b - Constants.

The two constants 'a' and 'b' in the above equation are obtained through a linear regression analysis. The computational procedure has been followed in the second method is as given below:

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

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

Where,

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

b. Rainfall Infiltration Factor Method

The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of ground water level. However the ground water extraction estimation included in the computation of rainfall recharge using water level fluctuation approach is often subject to uncertainties. Therefore, the rainfall recharge obtained from water level fluctuation approach has been compared with that estimated using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship –

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

Where,

R_{RF} - Rainfall recharge in ham

A - Area in hectares

RFIF - Rainfall Infiltration Factor

R- Rainfall in mm

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

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

c. Percent Deviation

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

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

Where,

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

R_{RF} (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

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

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

2. Recharge from Other Sources

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

Sl. No.	Source	Estimation Formula	Parameters
1	Recharge from Canals	$R_C = WA \times SF \times Days$	R_C = Recharge from Canals WA = Wetted Area SF = Seepage Factor Days = Number of Canal Running Days
2	Recharge from Surface Water Irrigation	$R_{SWI} = AD \times Days \times RFF$	R_{SWI} = Recharge due to applied surface water irrigation AD = Average Discharge Days = Number of days water is discharged to the Fields RFF = Return Flow Factor
3	Recharge from	$R_{GWI} = GE_{IRR} \times RFF$	R_{GWI} = Recharge due to applied ground

Sl. No.	Source	Estimation Formula	Parameters
	Ground Water Irrigation		water irrigation GE_{IRR} = Ground Water Extraction for Irrigation RFF = Return Flow Factor
4	Recharge due to Tanks & Ponds	$R_{TP} = AWSA \times N \times RF$	R_{TP} = Recharge due to Tanks & Ponds AWSA = Average Water Spread Area N = Number of days Water is available in the Tank/Pond RF = Recharge Factor
5	Recharge due to Water Conservation Structures	$R_{WCS} = GS \times RF$	RWCS = Recharge due to Water Conservation Structures GS = Gross Storage = Storage Capacity multiplied by number of fillings. RF = Recharge Factor

3. Evaporation and Transpiration

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

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

4. Recharge During Monsoon Season

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

5. Recharge During Non-Monsoon Season

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

6. Total Annual Ground Water Recharge

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

7. Annual Extractable Ground Water Resource (EGR)

The Annual Extractable Ground Water Resource (EGR) is computed by deducting the Total Annual Natural Discharge from Total Annual Ground Water Recharge.
In the water level fluctuation method, a significant portion of base flow is already accounted for by taking the post monsoon water level one month after the end of rainfall. The base flow in the remaining non-monsoon period is likely to be small, especially in hard rock areas. In the assessment units, where river stage data are not available and neither the detailed data for quantitative assessment of the natural discharge are available, allocation of unaccountable natural discharges to 5% or 10% of annual recharge is considered. If the rainfall recharge is assessed using water level fluctuation method this has been taken 5% of the annual recharge and if it is assessed using rainfall infiltration factor method, 10% of the annual recharge is considered. The balance is account for Annual Extractable Ground Water Resources (EGR).

8. Estimation of Ground Water Extraction

Ground water draft or extraction is assessed as follows.

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

Where,

GE_{ALL} = Ground water extraction for all uses
GE_{IRR} = Ground water extraction for irrigation
GE_{DOM} = Ground water extraction for domestic uses
GE_{IND} = Ground water extraction for industrial uses

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

The methods for estimation of ground water extraction are as follows.

***Unit Draft Method:* –** In this method, season-wise unit draft of each type of well in an assessment unit is estimated. The unit draft of different types (eg. Dug well, Dug cum bore well, shallow tube well, deep tube well, bore well etc.) is multiplied with the number of wells of that particular type to obtain season-wise ground water extraction by that particular structure.

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

***Power Consumption Method:* –**Ground water extraction for unit power consumption (electric) is determined. Extraction per unit power consumption is then multiplied with number of units of power consumed for agricultural pump sets to obtain total ground water extraction for irrigation.

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

There are several methods for estimation of extraction for domestic use(GEDOM). Some of the commonly adopted methods are described here.

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

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

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

Where,

L_g = Fractional Load on Ground Water for Domestic Water Supply.

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

c. Ground Water Extraction for Industrial Use (GE_{IND})

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

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

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

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

Where,

L_g = Fractional load on ground water for industrial water supply.

The load on ground water for industrial water supply can be obtained from water supply agencies in the Industrial belt.

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

9. Stage of Ground Water Extraction

The stage of ground water extraction is defined by,

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

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

10. Validation of Stage of Ground Water Extraction

The assessment based on the stage of ground water extraction has inherent uncertainties. In view of this, it is desirable to validate the 'Stage of Ground Water Extraction' with long term trend of ground water levels. Long term Water Level trends are prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. If the ground water resource assessment and the trend of long term water levels contradict each other, this anomalous situation requires a review of the ground water resource computation, as well as the reliability of water level data. The mismatch conditions are enumerated below.

SOGWE	Ground Water Level Trend	Remarks
≤ 70%	Significant decline in trend in both pre-monsoon and post-	Not acceptable and needs

	monsoon	reassessment
> 100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs reassessment

11. Categorisation of Assessment Unit

a. Categorisation of Assessment Unit Based on Quantity

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

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

b. Categorization of Assessment Unit Based on Quality

As it is not possible to categorize the assessment units in terms of the extent of quality hazard, based on the available water quality monitoring mechanism and database on ground water quality, the Committee recommends that each assessment unit, in addition to the Quantity based categorization (safe, semi-critical, critical and over-exploited) should bear a quality hazard identifier. If any of the three quality hazards in terms of Arsenic, Fluoride and Salinity are encountered in the assessment sub unit in mappable units, the assessment sub unit has been tagged with the particular Quality hazard.

12. Allocation of Ground Water Resource for Utilization

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

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

Where,

Alloc = Allocation for domestic water requirement

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

L_g= fractional load on ground water for domestic water supply (≤ 1.0)

13. Net Annual Ground Water Availability for Future Use

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

b. NORMS HAS BEEN USED IN THE ASSESSMENT

i. Specific Yield

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

Table-2.1: Norms Recommended for Specific Yield

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

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

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
				Cenozoic			
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	KarstifiedMiliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	Karstified Limestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	Karstified Limestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	Karstified Limestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	Karstified Marble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	0.3	0.2	0.4
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	3	2	4
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN0	Migmatitic Gneiss -	Azoic	0.3	0.2	0.4

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
		3	Massive, Poorly Fractured				
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

ii. Rainfall Infiltration Factor

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

Table-2.2: Norms Recommended for Rainfall Infiltration Factor

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

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

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
25	Limestone	LS01	Miliolitic Limestone	Quarternary	6	5	7
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	6	5	7
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	6	5	7
31	Limestone	LS04	Limestone with Shale	Proterozoic	6	5	7
33	Limestone	LS05	Marble	Azoic to Proterozoic	6	5	7
35	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.) - Weathered , Jointed	Mesozoic to Cenozoic	7	5	9
36	Granite	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)-Massive or Poorly Fractured	Mesozoic to Cenozoic	2	1	3
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	11	10	12
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	7	5	9
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
41	Schist	SC02	Phyllite	Azoic to Proterozoic	4	3	5
42	Schist	SC03	Slate	Azoic to Proterozoic	4	3	5
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	6	5	7
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	6	5	7
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	5	4	6
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	2	1	3
49	Khondalite	KH01	Khondalites, Granulites -	Azoic	7	5	9

Sl. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
			Weathered, Jointed				
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	2	1	3
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	7	5	9
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	2	1	3
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	7	5	9
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	2	1	3

iii. Norms for Canal Recharge

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

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

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

All canals in hard rock area	3.5	3	4

iv. Norms for Recharge Due to Irrigation

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

Table-2.4: Norms Recommended for Recharge from Irrigation

DTW m bgl	Ground Water		Surface Water	
	Paddy	Non-paddy	Paddy	Non-paddy
≤ 10	45.0	25.0	50.0	30.0
11	43.3	23.7	48.3	28.7
12	40.4	22.1	45.1	26.8
13	37.7	20.6	42.1	25.0
14	35.2	19.2	39.3	23.3
15	32.9	17.9	36.7	21.7
16	30.7	16.7	34.3	20.3
17	28.7	15.6	32.0	18.9
18	26.8	14.6	29.9	17.6
19	25.0	13.6	27.9	16.4
20	23.3	12.7	26.0	15.3
21	21.7	11.9	24.3	14.3
22	20.3	11.1	22.7	13.3
23	18.9	10.4	21.2	12.4
24	17.6	9.7	19.8	11.6
≥ 25	20.0	5.0	25.0	10.0

v. Norms for Recharge due to Tanks & Ponds

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

vi. Norms for Recharge due to Water Conservation Structures

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

vii. Unit Draft

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

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

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

$$\textit{Normalised Unit Draft} = \frac{\textit{Unit Draft} \times \textit{Rainfall for the year}}{\textit{Normal Rainfall}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

$$\textit{Normalised Unit Draft} = \frac{\sum_{i=1}^{n} \textit{Unit Draft}_i}{\textit{Number of Years}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$$

Chapter 3

INDIA -GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES)

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

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

3.1 PROCEDURE FOLLOWED IN THE PRESENT ASSESSMENT

The Dynamic Ground Water Resource Assessment (GWRA-2024) of UT of Daman and Diu and Dadra & Nagar Haveli has been computed as per GEC-2015 Methodology. Since the area of Daman and Diu and Dadra & Nagar Haveli districts are very small, therefore the district administrative boundary has been taken as assessment unit and for computing the district wise ground water resources. The Resource Estimation has been done by IN-GRES Software. In absence of requisites data or inadequacy if any, the constraints and the procedure followed in the present assessment are described below.

Data Sources and Constraint for Various Data Elements

All-out efforts were made to collect the data from the respective UT of Daman & Diu. However, it is felt necessary to mention that due to non-availability/constraint of some data, certain assumptions have been made while making the computations. The data sources for the various data elements used in the present exercise are presented in the following table no 3.1.

Table 3.1- Data Sources Used in the Ground Water Resource Estimation 2024

S.No	Data Element	Used in the Computation of	Data Source
1	Areas and Maps of 3 administrative /assessment Units.	Assessment unit wise recharge & draft component.	Revenue Dept, Govt. of Gujarat, Gandhinagar.
2	Irrigation Well.	Groundwater extraction for irrigation	Irrigation department, Daman, Diu and DNH
3	Ground Water Abstraction Details.	Groundwater extraction for Industrial.	Industrial development department, Daman, Diu and DNH
4	Ground Water Abstraction Details	Groundwater extraction for Domestic.	PWD Department and BDO office of Daman, Diu and DNH.
5	Population Census	Groundwater extraction for domestic purpose, Future allocation for domestic requirement.	Census of India Data (2011)
6	Load Factor (Lg)	As above	PWD Department of Daman, Diu and DNH
7	Details of Pump sets (HP) used in irrigation wells	Ground water extraction for irrigation purpose	BDO office of Daman, Diu and DNH
8	Canal details	Return Seepage Recharge due to Canals / Drains	PWD Department of Daman, Diu and DNH
9	Details of Tanks & Ponds, Check dams	Recharge due to Tanks & ponds & water conservation	PWD Department & BDO office of Daman, Diu and DNH
10	Rainfall	Recharge due to Rainfall / Normalization of Rainfall Recharge	IMD/State Water Data Centre
12	Ground Water Monitoring: Pre-monsoon and Post- monsoon groundwater levels & trends and GW quality monitoring data of last decade (2010-19).	Water Level Fluctuation method and validation of Stage of groundwater extraction, GW Quality data for identification of poor-quality area.	Central Ground Water Board, WCR, Ahmedabad and Gujarat Water Resources Development Corporation Ltd, Govt. of Gujarat
13	Data for Demarcation of Hilly Areas.	Hilly Area with slope less than 20% for Recharge.	BISAG, Gandhinagar

Long term 10 years (2014-23), pre-monsoon (May) and post-monsoon (November) water level data of observation wells monitored by CGWB, WCR, Ahmedabad are considered for calculating estimating zone of dynamic fluctuation and Water Level Trend. Water level fluctuations between pre-monsoon and post-monsoon have been calculated for hard rock and alluvial terrains separately. The Pre-monsoon and Post Monsoon water Level data is given in **Annexure 1**.

Due to insufficient/non-availability of data the following components were not considered while estimating the dynamic resources

- Lateral inflow/outflow across boundaries: insufficient data points / Piezometers for determination of the parameters.
- Subsurface inflow/outflow from hydraulically connected streams: sufficient nos. of stream gauge stations is required for determination of the parameters which were not available.

- Evaporation and Transpiration: water level is more than 3.5 mbgl in most of the areas for which data was available. Hence the same was not taken into account.

3.2 Domestic, Industrial extraction and future allocation for domestic use

Groundwater extraction for domestic use has been estimated and projected based on district wise population. Population daa of Census 2011 has been considered and has been projected till 2023 based on the annual growth rate of population as per Census 2011 data. The average consumption of 135 lpcd for Daman district, 120 lpcd for Diu district and 60 LPCD for Dadra & Nagar Haveli district and load factor (Lg) as supply from the public work department Daman and has been considered while estimating the domestic draft. Similarly, future allocation for domestic use has been estimated up to 2027 based on projected population in 2027 using Census 2011 data.

Ground water draft for industrial use of 3 district groundwater abstraction details provided by Daman, Diu & DNH Industrial Development department has been considered for estimating the Industrial Draft.

3.3 Irrigation Extraction:

District wise ground water extraction for irrigation was estimated based on the number of structures and the unit draft of different structures. As in the UT of DNH, Daman & Diu, major irrigation draft is through energized wells, data of HP wise number of irrigation connections in each taluka, average ground water draft based on HP of pump used in alluvial and hard rock formation and duration of pumping were used for estimation the irrigation draft.

3.4 Assessment Unit Area

The groundwater resource assessment of the UT of DNH, Daman & Diu has been carried out taking district (administrative boundary) as assessment unit. In total there are three (03) districts as assessment units. The details of ground water assessment units district wise is given as **Table-5**.

3.5 Norms Followed in the Assessment GWRA 2024

The GEC 2015 recommends that the state agencies should be encouraged to conduct field studies for various norms and use such computed norms in the assessment. In absence of such computed norms by the field study, GEC 2015 suggests to use recommended norm values for assessment, unless sufficient data based on field study are available to justify the minimum, maximum or other intermediate values.

Whereas specific yield values based on the field tests conducted by Central Ground Water Board & Gujarat Water Resources Development Corporation has been used in assessment, norms as suggested in GEC 2015 methodology like rainfall infiltration factor, canal seepage factor, factors for return flow from surface and ground water irrigation, recharge from water conservation structures, tanks and ponds etc., have been used.

3.6 Dynamic Ground Water Resources

3.6.1 Groundwater Potential

The assessment unit (District) wise details of groundwater potential are given in **Table–11.** The Total Annual Ground Water Recharge (TAGWR) for UT of DNH, Daman & Diu is estimated to be 12335.91 Ham/year and the Annual Extractable Ground Water Resource (AEGWR) after deducting natural discharge is estimated to be 11577.14 Ham/year. Groundwater extraction for irrigation is estimated at 1145.92 Ham/year whereas groundwater extraction for Industrial and domestic Extraction is estimated at 14021.25 Ham/year and 1292.4 Ham/year (UT of Dadar Nagar Haveli). Thus, the net ground water availability for future use is estimated to be 794.29 Ham/year. The Stage of Ground Water Extraction for DNH, Daman and Diu worked out to be 130.53%, 158.77% and 231.6% respectively for the year 2024. The UT of DNH, Daman & Diu in whole categorize as Over-exploited.

3.6.2 Categorization of Districts (Assessment Units)

As per the Dynamic Ground Water Resources Assessment as on March 2024, all three **assessment units Dadra and Nagar Haveli, Daman and Diu** is categorized as **OVER-EXPLOITED (Fig 09, 10 & 11).**

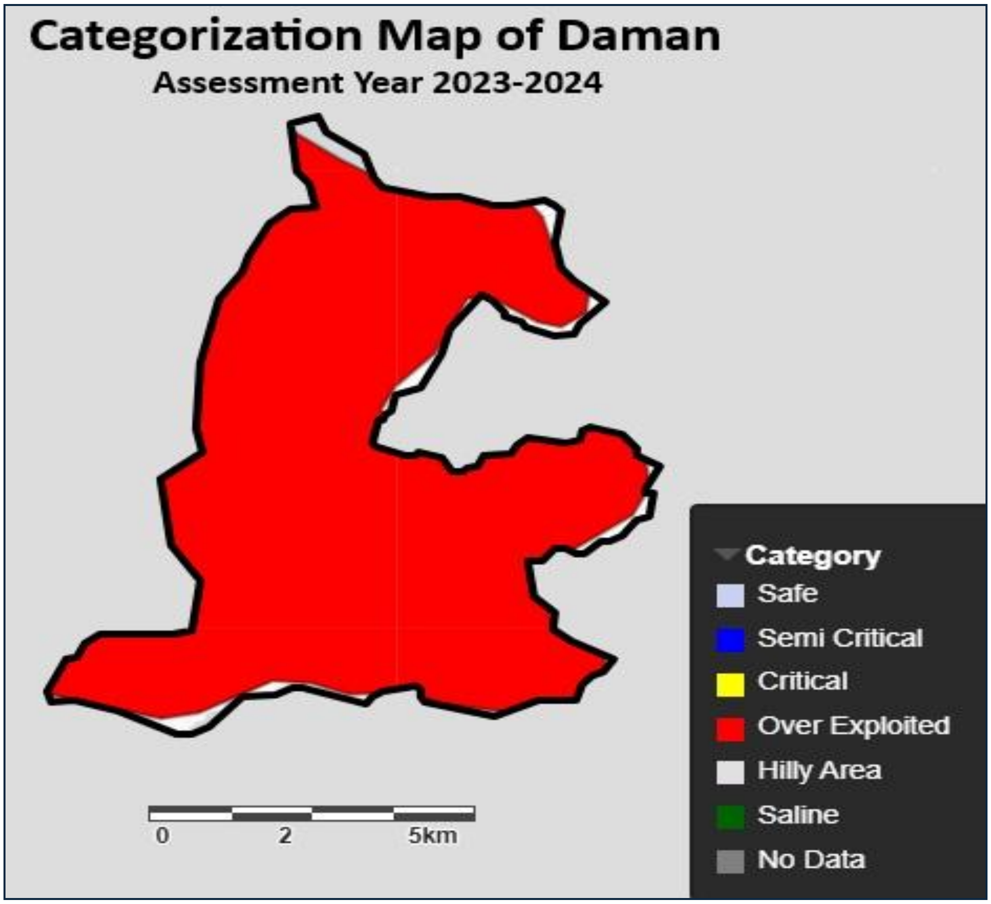

Figure 9- Categorization Map of Daman district as per GWRA-2024

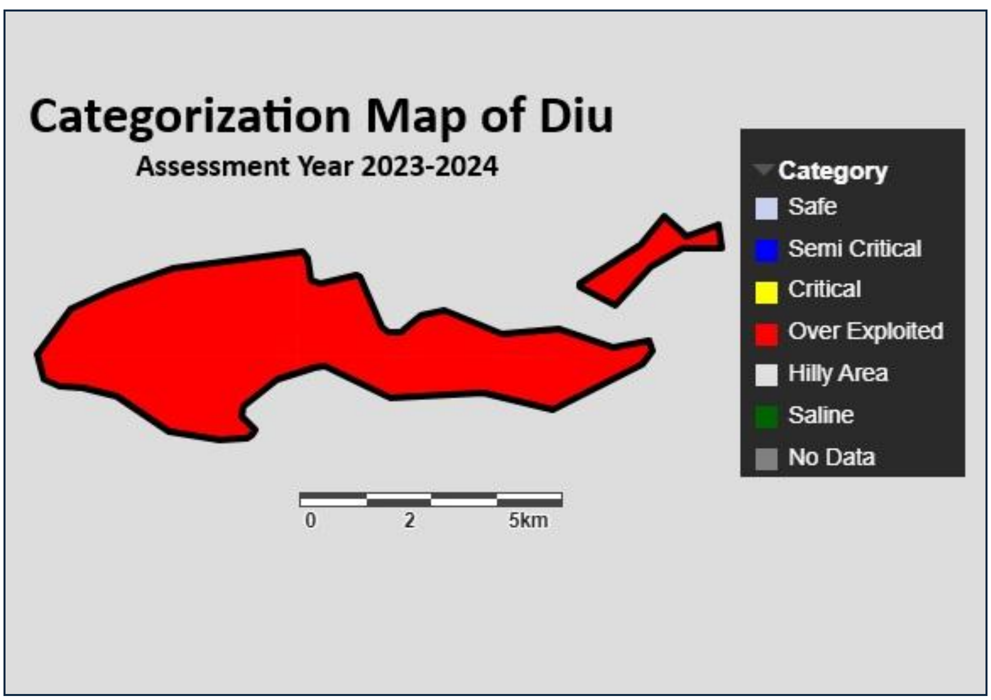

Figure 10- Categorization Map of Diu district as per GWRA-2024

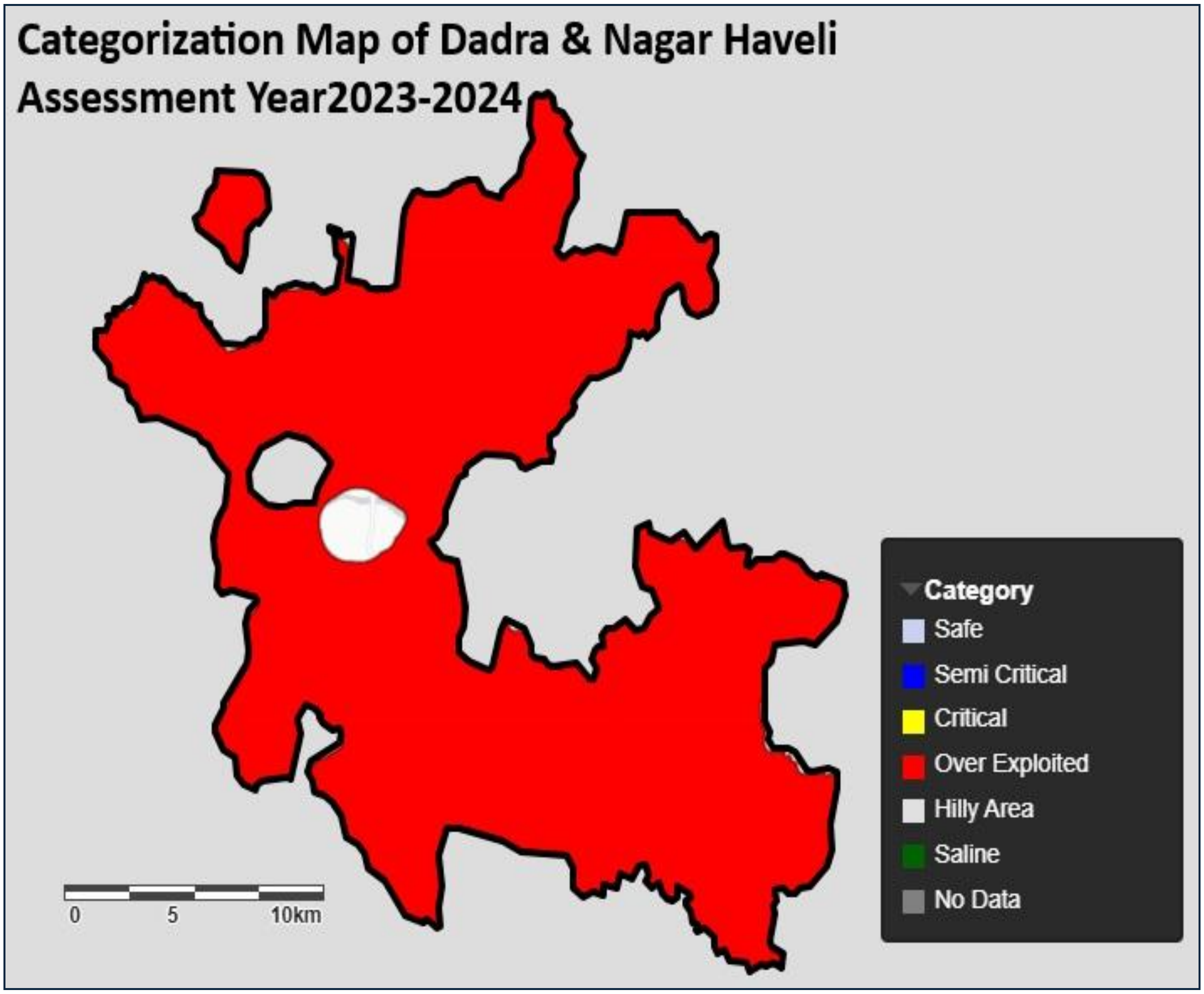

Figure 11- Categorization Map of DNH district as per GWRA-2024

3. Summary of findings of Report on Dynamic Ground Water Resources of UT of Daman & Diu- 2024

The Ground Water Resource Assessment of UT of Daman & Diu and Dadra & Nagar Haveli has been computed as per GEC-2015 Methodology. The administrative district boundary has been taken as assessment unit and for computing the district wise ground water resources. The Resource Estimation has been done by IN-GRES Software.

The ground water resources have been assessed district-wise.

In UT of Daman &Diu:- Total Annual Ground Water Recharge has been assessed as 0.035 BCM and Annual Extractable Ground Water Resources as 0.033 BCM. The total current Annual Ground Water Extraction has been assessed as 0.057 BCM. Over all the Stage of Ground Water Extraction is 171% (Daman 158.77% and Diu 231.63%) and categorized as 'Over Exploited'.

In UT of Dadra and Nagar Haveli: - Total Annual Ground Water Recharge has been assessed as 0.088 BCM and Annual Extractable Ground Water Resources as 0.082 BCM. The total current Annual Ground Water Extraction has been assessed as 0.107 BCM. Over all the Stage of Ground Water Extraction is 130.53% and categorized as 'Over Exploited'.

Out of 526.9 KM^2 recharge worthy area of the UT, the entire area is under 'Over-Exploited'. Total 115.77 MCM annual extractable ground water resources of the UT, 100% is under 'Over-exploited' categories of assessment units

Table 2- Dynamic Ground Water Resources of UT of Daman, Diu and Dadra & Nagar Haveli

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024															
DAMAN AND DIU AND Dadra & NAGAR HAVELI															
S.NO	Name of District	Ground Water Recharge					Total Natural Discharges	Annual Extractable Ground Water Resource	Current Annual Ground Water Extraction				Annual GW Allocation for Domestic use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)
		Monsoon Season		Non-Monsoon Season		Total Annual Ground Water Recharge			Irrigation	Industrial	Domestic	Total			
		Recharge from rainfall	Recharge from other Sources	Recharge from Rainfall	Recharge from other Sources										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	DAMAN	2824.29	41.21	0	71.91	2937.41	146.88	2790.53	215.1	4215.38	0	4430.48	1412.67	0	158.77
2	DIU	545.42	14.13	0	23.09	582.64	29.13	553.51	42.2	1239.89	0	1282.09	175.69	0	231.63
3	DADRA NAGAR HAVELI	5876.08	661.93	329.73	1948.12	8815.86	582.76	8233.1	888.62	8565.98	1292.4	10747	1798.23	794.29	130.53
	Total(Ham)	9245.79	717.27	329.73	2043.12	12335.91	758.77	11577.14	1145.92	14021.25	1292.4	16459.57	3386.59	794.29	142.17
	Total(Bcm)	0.0924579	0.0071727	0.0032973	0.0204312	0.1233591	0.0075877	0.1157714	0.011459	0.140213	0.01292	0.164596	0.0338659	0.0079429	142.17

Table 3- Total Annual Extractable Resource of Assessed Units (in mcm)

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024												
DAMAN AND DIU AND DADRA & NAGAR HAVELI												
S.No	Name of District	Total Annual Extractable Resource of Assessed Units (in mcm)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%	Total Annual Extractable Resource (in mcm)	%
1	DAMAN	27.91	-	-	-	-	-	-	27.91	100	-	-
2	DIU	5.54	-	-	-	-	-	-	5.54	100	-	-
1	DADRA NAGAR HAVELI	82.33	-	-	-	-	-	-	82.33	100	-	-
	Total	115.78	-	-	-	-	-	-	115.78	100		
	Grand Total	203.65	-	-	-	-	-	-	203.65	100		

Table 4- Total Geographical Area of Assessed Units (in sq km)

AREA OF ASSESSMENT UNITS UNDER DIFFERENT CATEGORIES IN INDIA (2024)														
S.No	States / Union Territories	Total Geographical Area of Assessed Units (in sq km)	Recharge Worthy Area (in sq km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
				Recharge Worthy Area in sq km	%	Recharge Worthy Area in sq. km	%	Recharge Worthy Area in sq. km	%	Recharge Worthy Area in sq km	%	Recharge Worthy Area in sq km	%
1	**DAMAN AND DIU**	112	110.9	-	-	-	-	-	-	110.9	100	-	-
2	**DADRA AND NAGAR HAVELI**	491	416	-	-	-	-	-	-	416	100	-	-
	Total	603	526.9	-	-	-	-	-	-	526.9	100	-	-
	Grand Total	603	526.9	-	-	-	-	-	-	526.9	100	-	-

Table 5- Total Recharge Worthy Area of Assessed Units (in sq.km)

DYNAMIC GROUND WATER RESOURCES OF INDIA, 2024													
DAMAN AND DIU AND DADRA & NAGAR HAVELI													
S.No	Name of District	Total Recharge Worthy Area of Assessed Units (in sq.km)	Safe		Semi-Critical		Critical		Over-Exploited		Saline	
			Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%	Recharge Worthy Area of Assessed Units (in sq.km)	%
1	**DAMAN**	70.9	-	-	-	-	-	-	70.9	100.0	-	-
2	**DIU**	40	-	-	-	-	-	-	40	100.0	-	-
3	**DADRA NAGAR HAVELI**	416	-	-	-	-	-	-	416	100.0	-	-
	Total	526.9	-	-	-	-	-	-	526.9	100.0	-	-

Table 6- CATEGORISATION OF ASSESSMENT UNIT

CATEGORISATION OF ASSESSMENT UNIT, 2024							
DAMAN AND DIU AND Dadra & NAGAR HAVELI							
S.NO	Name of District	S.NO	Name of Semi-Critical Assessment Units	S.NO	Name of Critical Assessment Units	S.NO	Name of Over-Exploited Assessment Units
1	DAMAN					1	DAMAN
2	DIU					1	DIU
3	DADRA NAGAR HAVELI					1	DADRA NAGAR HAVELI

ABSTRACT			
Total No. of Assessed Units	Number of Semi-critical Assessment Units	Number of Critical Assessment Units	Number of Over Exploited Assessment Units
3	0	0	3

Table 7- State-Wise Summary of Assessment Units Improved or Deteriorated

State-Wise Summary of Assessment Units Improved or Deteriorated From 2023 To 2024 Assessment				
S.No	Name of States / Union Territories	Number of Assessment Units Improved	Number of Assessment Units Deteriorated	Number of Assessment Units with No Change
1	DAMAN AND DIU AND DADRA & NAGAR HAVELI	0	0	3

Table 8- Geographical Area Vs. Recharge Worthy Area Vs. Hilly Area (ha)

Geographical Area Vs. Recharge Worthy Area Vs. Hilly Area							
S.No	DISTRICT	Total Geographical Area (ha)					
		Recharge Worthy Area (ha)				Hilly Area	Total
		C	NC	PQ	Total		
1	DAMAN	6840	0	250	7090	110	7200
2	DIU	3676	0	324	4000	0	4000
1	DADRA NAGAR HAVELI	4235	37365	0	41600	7500	49100
Total		14751	37365	574	52690	7610	60300

Table 9- Attribute Table for GWRA 2024

Assessment Unit Name	Total Geographical Area (ha)	Recharge Worthy Area	Recharge from Rainfall-MON	Recharge from Other Sources-MON	Recharge from Rainfall-NM	Recharge from Other Sources-NM	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	Irrigation Use (Ham)	Industrial Use (Ham)	Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/Semicritical/Safe)
DAMAN	7200	7090	2824.29	41.21	0	71.91	2937.41	146.88	2790.53	215.1	4215.38	0	4430.48	1412.67	0	158.77	over_exploited
DIU	4000	4000	545.42	14.13	0	23.09	582.64	29.13	553.51	42.2	1239.89	0	1282.09	175.69	0	231.63	Over exploited
DADRA AND NAGAR HAVELI	49100	41600	5876.08	661.93	329.73	1948.12	8815.86	582.76	8233.1	888.62	8565.98	1292.4	10747	1798.23	794.29	130.53	over_exploited
Total (HAM)	60300	52690	9245.79	717.27	329.73	2043.12	12335.91	758.77	11577.14	1145.92	14021.25	1292.4	16459.57	3386.59	794.29	142.17	over_exploited
Total (BCM)			0.092	0.007	0.003	0.020	0.123	0.008	0.116	0.011	0.140	0.013	0.165	0.034	0.008	142.17	over_exploited

Annexure 1- Water Level Data

S.No	District	Year	Pre-monsoon Water Level (mbgl)	Post-Monsoon Water Level (mbgl)
1	DAMAN	2015	6	3.16
2	DAMAN	2016	6.13	3.1
3	DAMAN	2017	6.43	3.86
4	DAMAN	2018	6.53	2.91
5	DAMAN	2019	6.3	2.98
6	DAMAN	2020	6.92	2.77
7	DAMAN	2021	7.25	3.37
8	DAMAN	2022	7.85	3.42
9	DAMAN	2023	6.07	2.61
1	DIU	2015	5.08	4.25
2	DIU	2016	5.77	4.45
3	DIU	2017	5.78	4.14
4	DIU	2018	5.8	4.47
5	DIU	2019	5.85	4.67
6	DIU	2020	5.85	4.89
7	DIU	2021	5.97	4.93
8	DIU	2022	6.15	4.98
9	DIU	2023	5.73	5.11
1	DADRA NAGAR HAVELI	2014	7.38	5.88
2	DADRA NAGAR HAVELI	2015	7.15	5.26
3	DADRA NAGAR HAVELI	2016	8.06	4.83
4	DADRA NAGAR HAVELI	2017	9.2	5.15
5	DADRA NAGAR HAVELI	2018	7.59	6.17
6	DADRA NAGAR HAVELI	2019	9.81	4.47
7	DADRA NAGAR HAVELI	2020	9.81	4.47
8	DADRA NAGAR HAVELI	2021	9.81	4.47
9	DADRA NAGAR HAVELI	2022	9.62	4.15
10	DADRA NAGAR HAVELI	2023	6.87	4.96

Annexure 2- Yearly Rainfall Data (mm)

S.No	Assessment Unit	Year	Monsoon Rainfall (mm)	Monsoon Normal Rainfall (mm)
1	DAMAN	2015-2016	1333	2275
2	DAMAN	2016-2017	2113	2275
3	DAMAN	2017-2018	1973	2275
4	DAMAN	2018-2019	1834	2275
5	DAMAN	2019-2020	2962	2275
6	DAMAN	2020-2021	1676	2275
7	DAMAN	2021-2022	2382	2275
8	DAMAN	2022-2023	3100	2275
9	DAMAN	2023-2024	2398	2275
1	DIU	2013-2014	1157	923
2	DIU	2014-2015	909	923
3	DIU	2015-2016	1031	923
4	DIU	2016-2017	886	923
5	DIU	2017-2018	939	923
6	DIU	2018-2019	950	923
7	DIU	2019-2020	1100	923
8	DIU	2020-2021	1136	923
9	DIU	2021-2022	953	923
10	DIU	2022-2023	982	923
11	DIU	2023-2024	1070	923
1	DADRA NAGAR HAVELI	2014-2015	1937.15	1925.9
2	DADRA NAGAR HAVELI	2015-2016	1346.4	1925.9
3	DADRA NAGAR HAVELI	2016-2017	1972.85	1925.9
4	DADRA NAGAR HAVELI	2017-2018	3081	1925.9
5	DADRA NAGAR HAVELI	2018-2019	1781.6	1925.9
6	DADRA NAGAR HAVELI	2019-2020	2683.7	1925.9
7	DADRA NAGAR HAVELI	2020-2021	2202	1925.9
8	DADRA NAGAR HAVELI	2021-2022	2382	1925.9
9	DADRA NAGAR HAVELI	2022-2023	3100	1925.9
10	DADRA NAGAR HAVELI	2023-2024	2398	1925.9