केन्द्रीय भूमिजल बोर्ड

जल शक्ति मंत्रालय, जल संसाधन, नदी विकास और गंगा संरक्षण विभाग

भारत सरकार

Central Ground Water Board

Ministry of Jal Shakti,
Department of Water Resources, River Development
and Ganga Rejuvenation
Government of India

Report on

AQUIFER MAPPING AND MANAGEMENT PLAN

Udupi Taluk, Udupi District, Karnataka

दक्षिण पश्चिमी क्षेत्र, बेंगलुरु

South Western Region, Bengaluru

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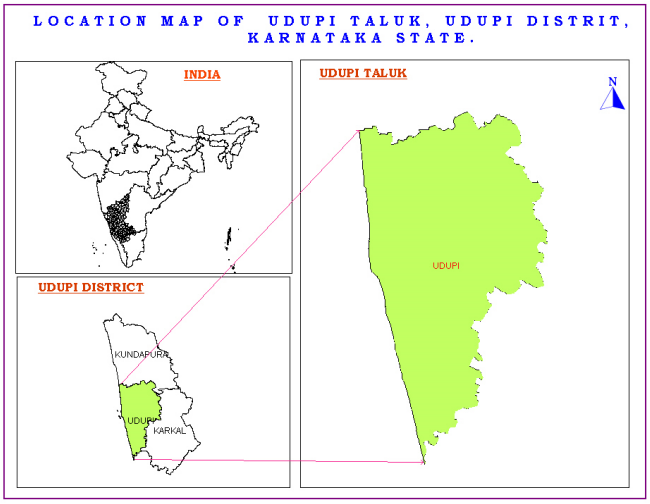
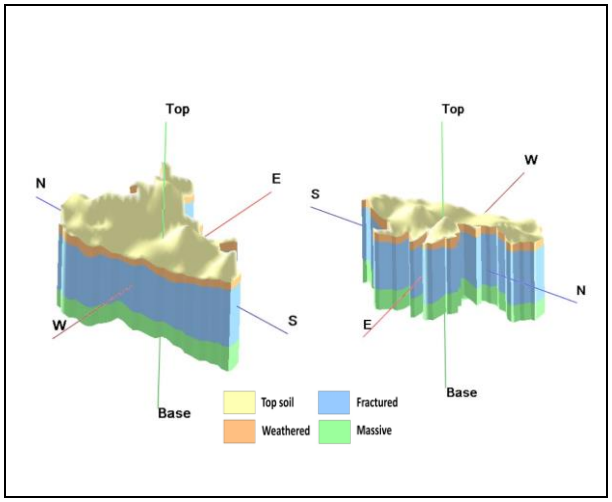
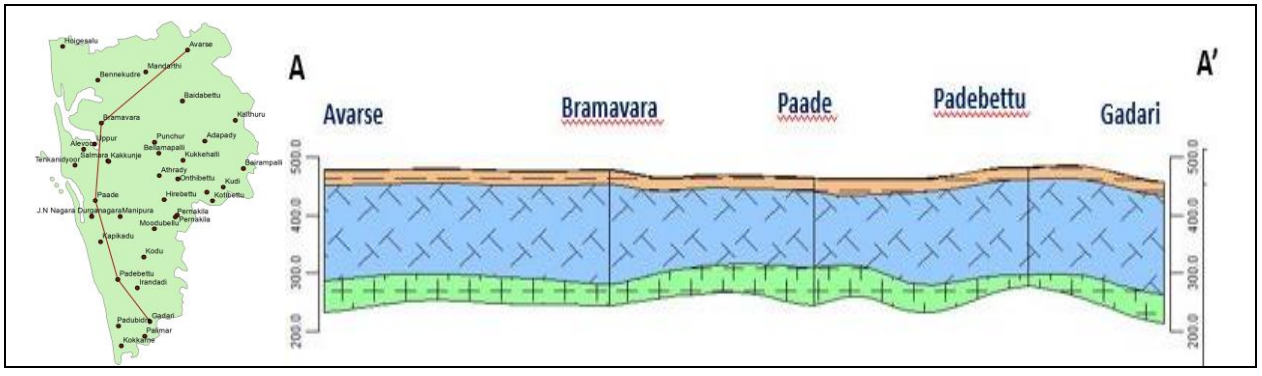
AQUIFER MAPS AND MANAGEMENT PLAN, UDUPI TALUK, UDUPI DISTRICT, KARNATAKA STATE

(AAP – 2022-2023)







By

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MAY 2023

AQUIFER MAPS AND MANAGEMENT PLAN, UDUPI TALUK, UDUPI DISTRICT, KARNATAKA STATE

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AQUIFER MAPS AND MANAGEMENT PLAN, UDUPI TALUK, UDUPI DISTRICT, KARNATAKA STATE

1 SALIENT INFORMATION

Name of the taluk: **Udupi**

District: **Udupi**; State: Karnataka

Area: **942** sq.km.

Population: **5,62,799**

Annual Normal Rainfall: **3745** mm

1.1 Aquifer management study area

Aquifer mapping studies was carried out in Udupi Taluk, Udupi district of Karnataka, covering an area of **942** sq.kms under National Aquifer Mapping. Udupi Taluk of Udupi district is located between north latitude **13°16'** and **13°26'** & east longitude **74°51'** and **74°55'** and is covered in parts of Survey of India Toposheet Nos. 48K/10,11,12,14,15&16. It is bounded by Western Coast(Arabian sea) in West side, Kumdapur Taluk, Udupi District in North, Karkal taluk, Udupi district in East, Dakshin Kannada on the southern side. Location map of Udupi Taluk of Udupi district is presented in **Fig. 1.**

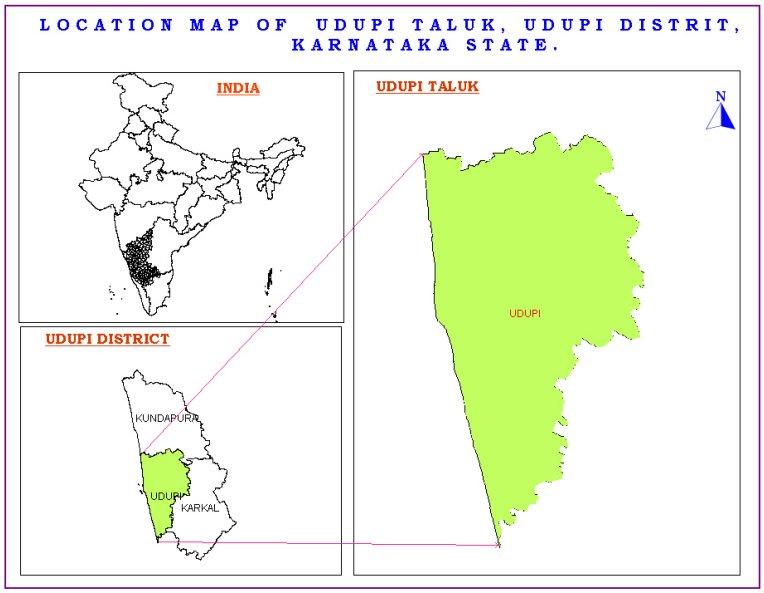


Fig. 1: Location Map of Udupi Taluk, Udupi district

Udupi taluk is taluk of Udupi District. Udupi taluk is the Headquarter of Udupi District. There are **4** Hoblis, **59** Gram panchayat and **86** villages in Udupi Taluk. Udupi is 422km west of state capital Bangalore by road and 55km north of educational, Commercial and Industrial hub of Mangalore taluk.

It is Administrative headquarter of Udupi District and one of the fastest growing cities of Karnataka. Udupi, which is previously had a town Municipal council, now has a city Municipal council which came into existence in 1995.

Population

According to 2011 census, the population of Udupi Taluk is **5,62,799**. Out of the total population 2,70,954 constitute the male population and 2,91,845 is the female population. The urban population is 2,60,707 and rural one is 3,02,092. Decadal change in population from 2001-2011 is 6.34 % in Udupi Taluk. Decadal change in rural and urban population is -19.78% and 70.79 % respectively. The density of population is **597** persons per square km.

1.2 Rainfall

Udupi Taluk has typical **Maritime climate**. Hot and Humid weather prevails in summer and pleasant during Winter. The taluk is marked by heavy rainfall, high humidity and oppressive weather in hot season. The weather is hot and humid throughout of the year. The year is usually divided into four seasons namely summer from March to May; rainy season or south-west monsoon season from June to September; post-monsoon season covering the months of October and November and dry or winter Season from December to February. April and May are regarded as the summer months with maximum temperature around 45 degree Celsius and minimum temperature is around 19 degree Celsius. The average annual rainfall is **3745** mm and rainfall is received mainly during the south-western monsoon extending from June to September.

There is **5** rain gauge station in Udupi Taluk, the rainfall data in respect of this station from the year 1981 to 2010 is analyzed. The data pertaining to these gauges is of long-term nature and are well maintained. It is presumed that they are representative of the Taluks and the same is used for analysis. Normal annual rainfall in the Taluk for the period 1981 to 2010 is **3745 mm**.

Computations were carried out for the **30** years blocks of **1981- 2010** on Mean, Standard deviation and coefficient of variation (CV) of each month pre -monsoon, monsoon, post monsoon and annual and are shown in **Table 1**.

The mean monthly rainfall at Udupi Taluk is ranging between 1 mm during January to 1039 mm during June. The CV percent for pre-monsoon, monsoon and post monsoon season is 90, 16 & 51 percent respectively. Annual CV at this station works out to be 15 percent.

Table-1: Statistical Analysis of Rainfall Data of Udupi taluk, Udupi district (1981 to 2010)

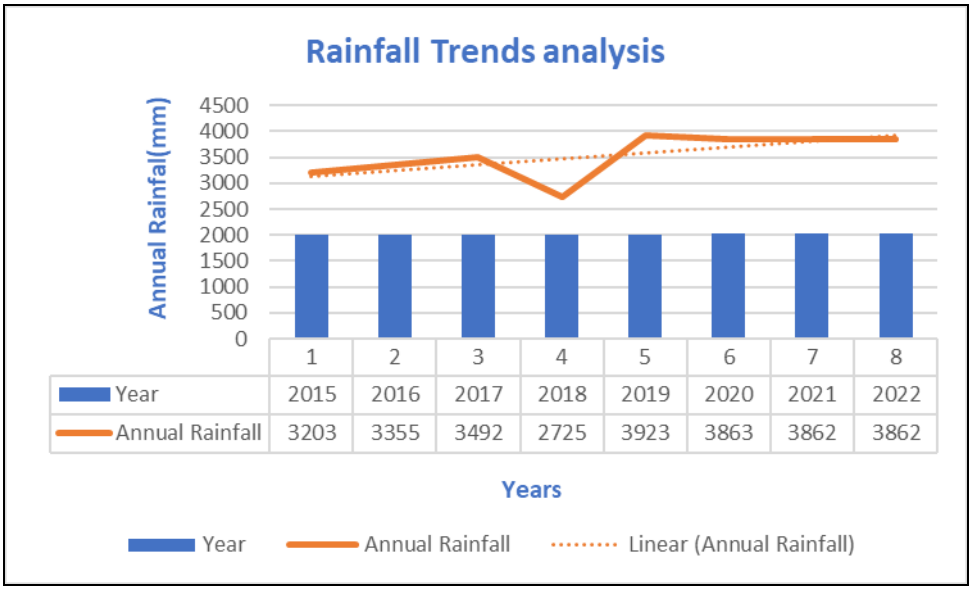
STATION		JAN	FEB	MAR	APR	MAY	PRE MONSOON	JUN	JUL	AUG	SEP	SOUTH WEST MONSOON	OCT	NOV	DEC	NORTH EAST MONSOON	ANNUAL RAINFALL
Udupi	Normal Rainfall (mm)	1	2	9	20	152	183	1039	1080	807	342	3268	210	74	10	294	**3745**
	STDEV	2	6	29	32	172	165	232	372	268	223	528	116	65	24	150	550
	CV%	237	377	339	159	113	90	22	34	33	65	16	55	88	247	51	15

Annual Rainfall (2015-2022)

Computation were carried out for the annual rain fall for the year 2015-2022.The annual rainfall from **2015-2022** for month is below **(Table-2).**

Table 2: Analysis of Annual Rainfall Data of Udupi Taluk, Udupi District, Karnataka for the Period 2015 to 2022

ANNUAL RAINFALL (2015-2022)																
Year	JAN	FEB	MAR	APR	MAY	PRE MONSOON	JUN	JUL	AUG	SEP	SOUTH WEST MONSOON	OCT	NOV	DEC	POSTMONSOON MONSOON	ANNUAL RAINFALL
2015	2	0	46	32	64	144	660	1136	631	270	2697	202	160	0	362	**3203**
2016	0	0	0	0	33	33	1502	946	533	276	3257	65	0	0	65	**3355**
2017	0	0	0	0	105	105	1200	933	779	302	3214	166	6	1	173	**3492**
2018	0	0	37	0	517	554	1059	895	70	60	2084	84	3	0	87	**2725**
2019	0	0	0	9	6	15	488	1018	1260	594	3360	486	56	6	548	**3923**
2020	1	1	6	26	180	214	1033	1214	781	340	3368	198	69	14	281	**3863**
2021	0.5	1	5.9	26.2	179.8	213	1033	1214	781	340	3368	198	69	14	281	**3862**
2022	0.5	1	5.9	26.2	180	213	1033	1214	781	340	3368	198	69	14	281	**3862**



Rainfall Trends analysis of Udupi Taluk

1.3 Agriculture & Irrigation

Agriculture is the main occupation in Udupi Taluk, since 53% of the total population constitutes the rural population. The amount of rainfall and its distribution throughout the season contributes to the cropping pattern in the area. There are two agricultural seasons namely Kharif (June – October) and Rabi season (Mid October – Mid February). Most of the agriculture is through open well,bore-well, lift irrigation and ground water is a major source of irrigation. Major Kharif crops are paddy and vegetables. Main crops of Rabi season is pulses. Among the commercial crops, Paddy is grown. Fruits and vegetables are also grown in the area (**Table 3**).

Table 3: Area wise crops grown in Udupi Taluk

Year	Paddy	Jowar	Maize	Banana	Coconut	Arecanuts	Total Pulses	Groundnut	Total plantation crop	Total fruits	Total vegetables	Total Food Grains
			Area under cultivation (in ha)									
2015-16	**18667**	-	-	-	-	-	2442	**445**	-	4676	645	21109

During the year 2015-16, percentage of gross sown area of total geographical area is **39.30 %** and net sown area was **34.62 %** in Udupi Taluk (**Table-4** and **Fig 2**). Irrigation practices by different sources in the Taluk are presented in **Table 5**.

Table 4: Land use pattern of Udupi Taluk

Year	Total Geographical Area (ha)	Area under Forest (ha)	Area not available for cultivation (ha)	Other uncultivated land (ha)	Total fallow land (ha)	Net sown area (ha)	Area sown more than once (ha)
2015-16	92798	4686	21068	28689	6228	32127	4350

Source: District at a Glance, 2015-16, Govt. of Karnataka

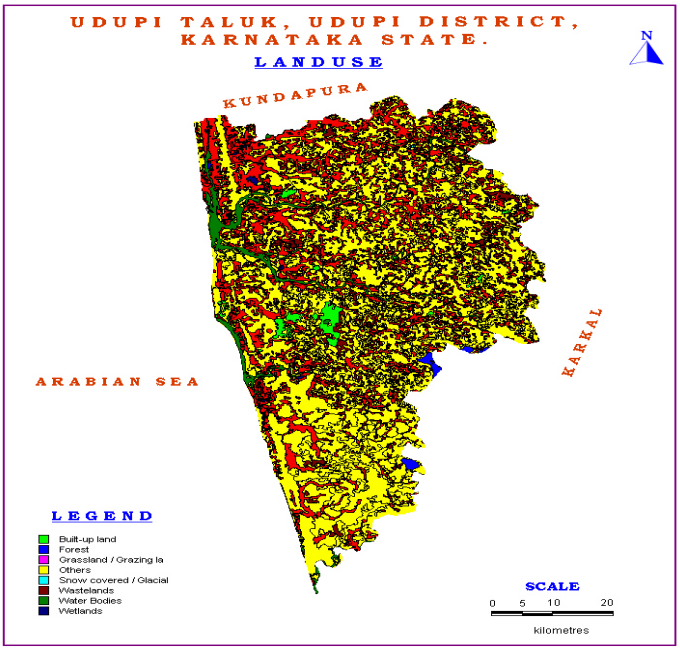
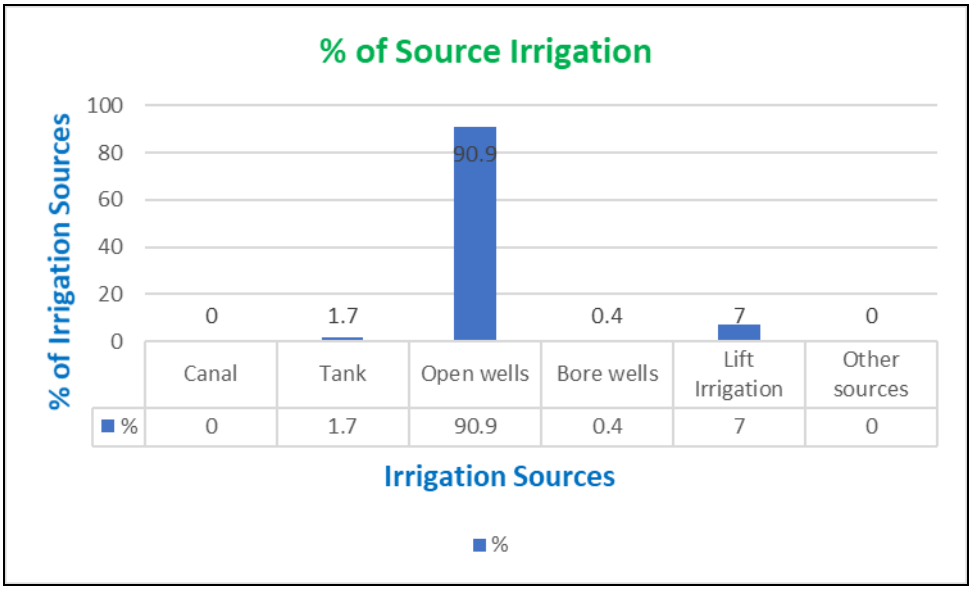


Fig. 2: Land use map

Table 5: Irrigation practice in Udupi Taluk

Source of irrigation	No. of irrigation source	Gross area irrigated (ha)	Net area irrigated (ha)
Canals	0	0	0
Tanks	155	271	271
Open Wells	8143	8143	7394
Tube/ Bore wells	35	35	35
Lift Irrigation	604	586	586
Other Sources	-	2066	1876
Total	**8937**	**11,101**	**10,162**

Source: District at a Glance, 2015-16, Govt. of Karnataka



Source of Irrigation in Udupi Taluk

1.4 Geomorphology, Physiography & Drainage

Geomorphologically, Udupi Taluk belongs to **West flowing region** which is characterized by Coastal plain in Western side and occur almost all over the taluk, Piedmont zone in spread in mostly central, eastern and southern part of taluk. (**Fig. 3)**.Coastal plain is a narrow, thickly populated and intensely cultivated area adjoining the coast. There is considerable extent of barren land along the coast partly because it is sandy, rocky and marshy. The area near the sea is covered with coconut garden. The piedmont zone interspersed which is moderately cultivated with a considerable extent of fallow land, which can be put to agriculture use. The hill and plateau capped with laterite, which form plateau usually of oval or elongated configuration.

Taluk come under **Coastal agro-climatic west flowing river basin** and Seetha river is mostly flow through Udupi taluk. They exhibit **dendritic to sub-dendritic drainage** pattern.(**Fig.4**.) **Seetha river** originated in Western ghat near Hebri at top of Narasimha Paravatha. It confluence with Suvarna river before joining Arabian sea.

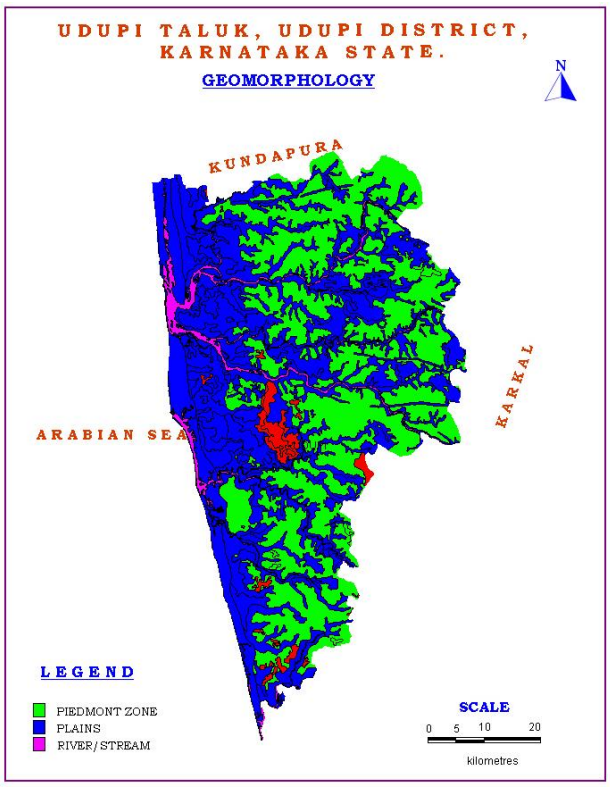


Fig. 3: Geomorphology map

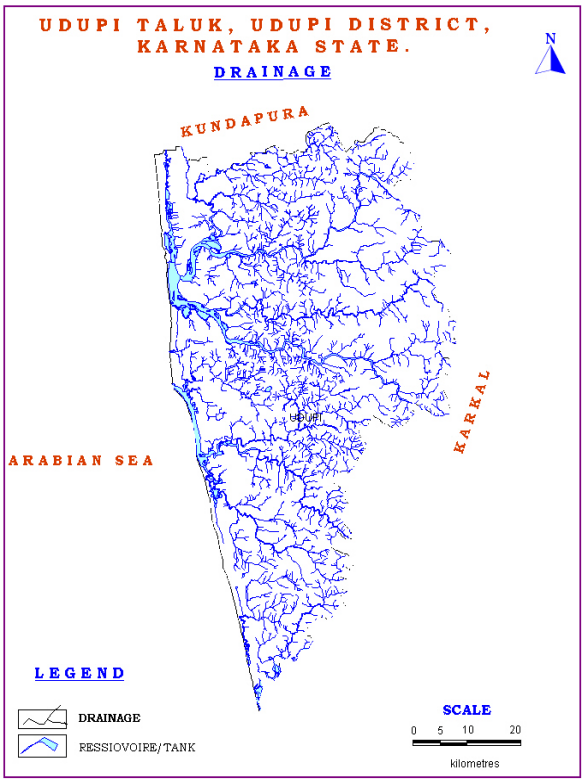


Fig. 4: Drainage map

1.5 Soil

The Taluk is mainly covered by clayey soil and varieties of **clayey soil like mixed and skeletal variety** found mostly all over the taluk.(**Fig. 5).** Soil derived from granite and gneiss with occasionally present of laterite type,characterised by High iron and aluminium content. Laterite type is suitable for Paddy, Sugarcane, Arecanut and Plantation crops. Sandy loamy are altered product of Granite gniesses, shallow to medium in depth intermixed with quartzite and gravelly material occur in central part of taluk. Loamy sand and sandy mostly occur near to Coastal area of Taluk.

Water holding capacity is Good. They have good Infiteration capacity and are well-suited for agriculture due to their fertility.

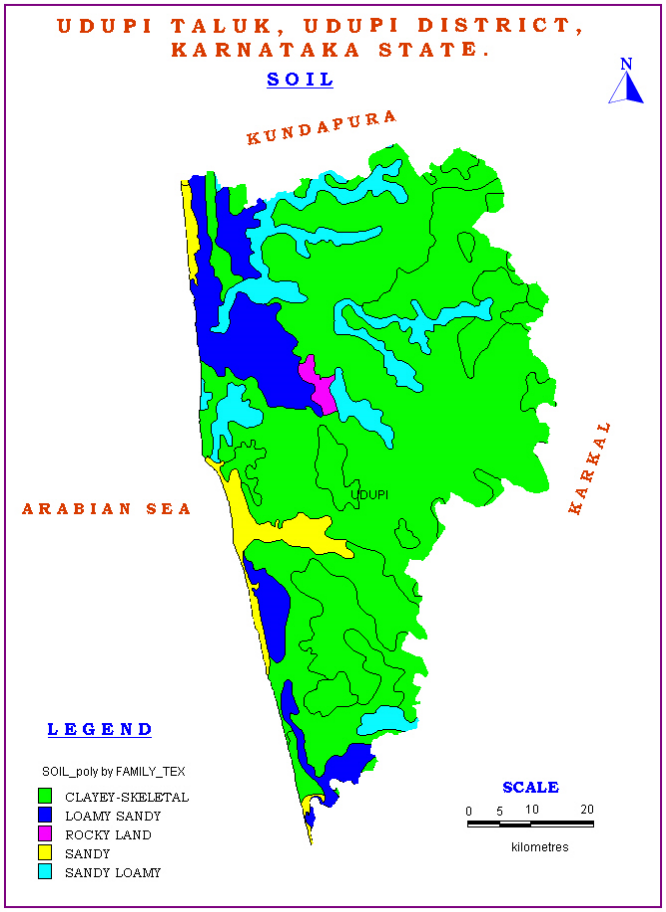


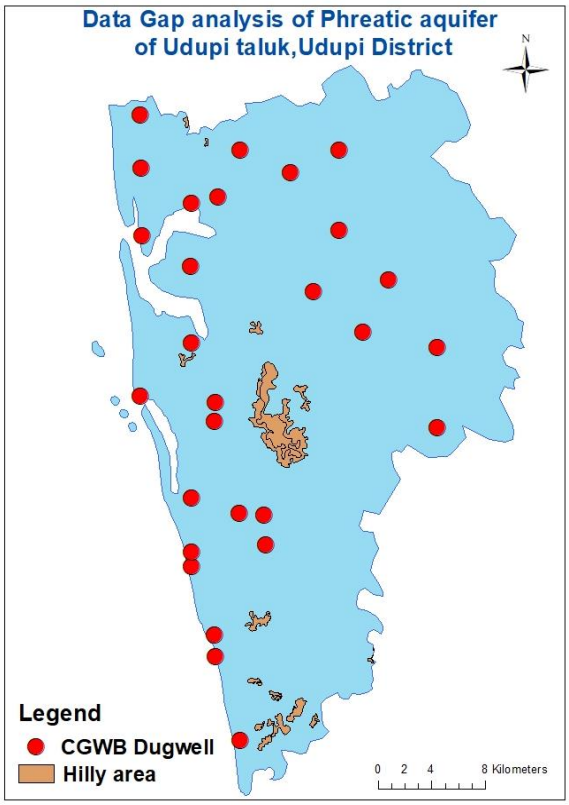
Fig. 5: Soil map

1.6 Existing and future water demands (as per GEC-2022) Table:6

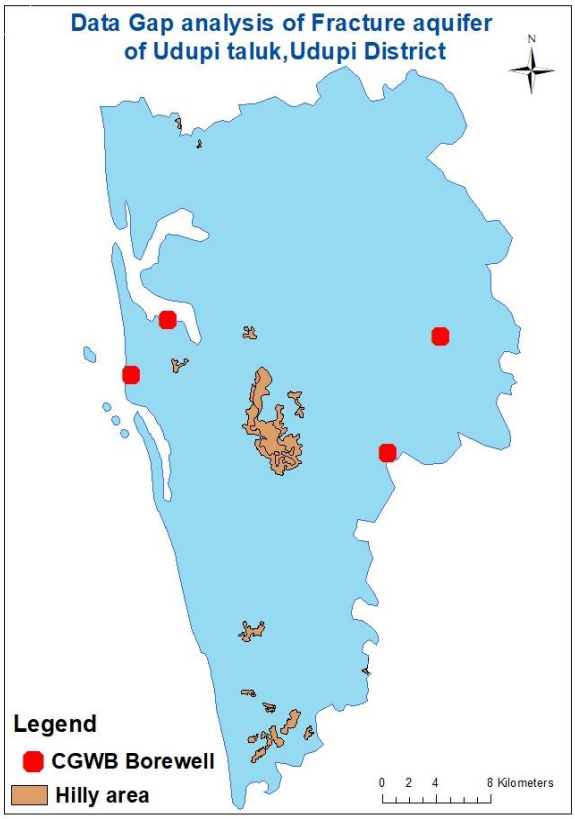
Year	Existing Gross GW extraction for Irrigation (ham)	Existing Gross GW extraction for domestic and industrial water supply (ham)	Allocation for domestic and industrial use for the next 25 years (ham)	Net GW availability for future Irrigation development (ham)	Existing stage of Groundwater development(%)
2017	3155	1155	1236	5124	**45**
2020	3636.896	1298.712	1370.99	13788.25	**26.3**
2022	4545.41	1104.67	1127.7	8579.54	**39.6**

1.7 Data Gap analysis and Well-Inventory with Pre-monsoon water-level Monitoring and Sample Collection

Pre-Monsoon water level monitoring generally analysed during May month. Based on the CGWB data Total **28** Dugwell and **1** Borewell present in the Udupi taluk for Monitoring. Dugwell mostly covered in the taluk and pre-monsoon water level has been collected from the well ranges **3.24 m bgl to 15 m bgl** in dug well **(Aquifer-1)** and **7.65 - 13.95 m** in Borewell **(Aquifer-2)** included state groundwater department data. From most of the **28** dugwell, water sample collection of Pre-Monsoon has been collected for Chemical Quality analysis.



Data Gap analysis of Phreatic Aquifer



Data Gap analysis of Fractured Aquifer

4 Borewell drilled in Udupi Taluk of shallow aquifer during Phase-1 of Drilling. Based on the available borewell data. It is showing that most of the taluk needs Data gap analysis and Well-Inventory for fractured aquifer.

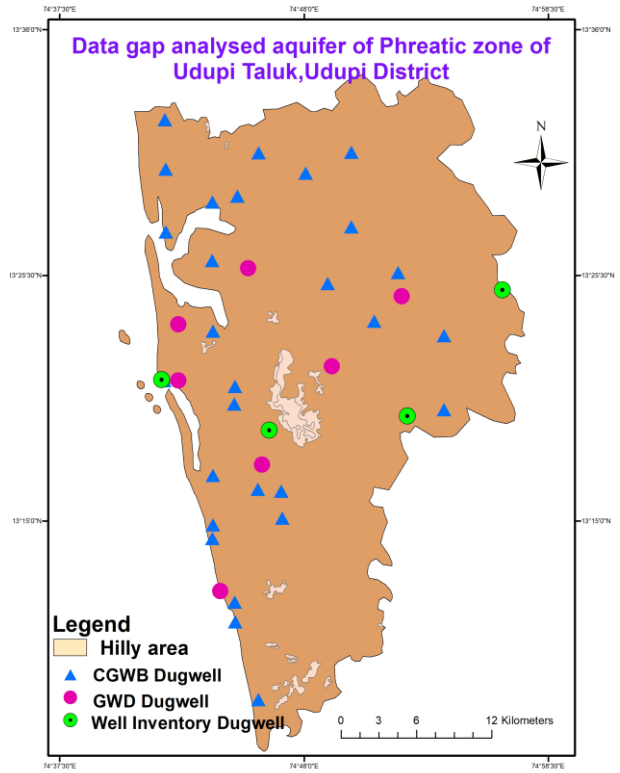
Proposed Villages should be covered under NAQUIM Studies based on Data gap analysis

S.N	VILLAGE NAME	LATITUDE	LONGITUDE	ELEVATION
1	**Herdi**	13.4178	74.9258	48m
2	**Alanger**	13.4061	74.9041	24m
3	**Byrampalli**	13.3660	74.9443	53m
4	**Damadka**	13.3780	74.9185	54m
5	**Bangarabailu**	13.3814	74.9002	33m
6	**Baje**	13.3733	74.8608	25m
7	**Punchur**	13.4035	74.8364	10m
8	**Bukkigude**	13.3282	74.9093	30m
9	**Kapikadu**	13.3447	74.8593	47m
10	**Herga**	13.3657	74.8111	35m
11	**Manipal**	13.3564	74.3932	60m
12	**Batrakodi**	13.3255	74.8297	32m
13	**Pernakila**	13.2964	74.8537	36m
14	**Padavu**	13.3285	74.7971	87m

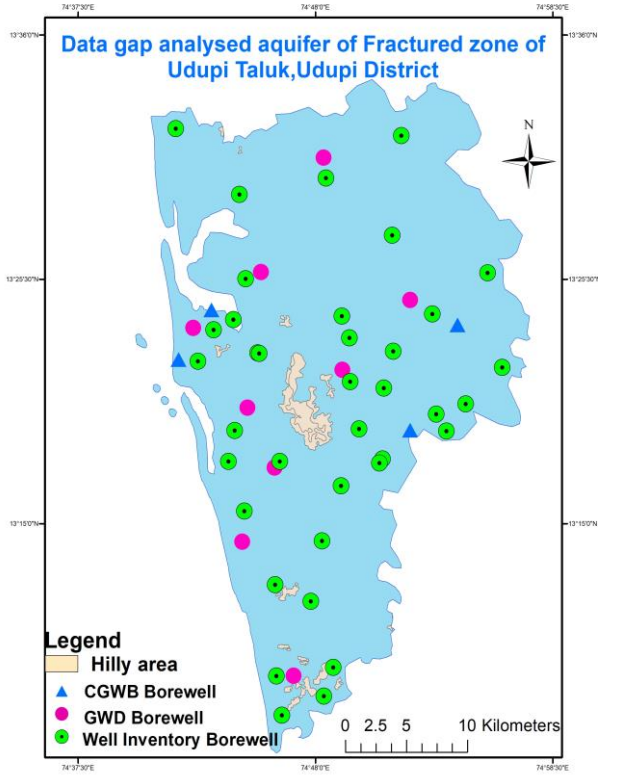
1.8 Data Gap analysed aquifer of Phreatic and Fractured aquifer

Based on the presence of Dugwell data, the Phreatic zone is covered mostly in all reliable zone except hilly areas and 4 Dugwell inventory has been done and 7 state government well utilized for data gap. Ground water exploration programme of CGWB was carried out in three phases in the district. There are few wells have been drilled in Udupi Taluk during 1st phase, which reveals that the weathered, jointed and fractured granite is the potential aquifer system. **4** Borewell drilled in Udupi Taluk during Phase-1 of Drilling. Based on the available borewell data. It is showing that most of the taluk needs Data gap analysis and Well-Inventory for fractured aquifer.

Data Gap analysis and Well-inventory conducted in total **37** villages in entire taluk and 9 state government well utilized. Based on the Well-Inventory, Total depth of well drilled, Discharge, Weathered zone, casing and Fractured zone data has been collected.



Data Gap analysed aquifer of Phreatic zone



Data Gap analysed aquifer of Fractured zone

1.9 Water level behavior

A. DEPTH TO WATER LEVEL OF AQUIFER-I:

The distribution of depth to water level of Phreactic aquifer in different depth ranges is presented . Salient features of the depth to water level scenario during **May 2022** and **Nov 22** are given below **(Table-7).**

Pre-Monsoon 2022 DTWL of Aq-I-(Fig-6A)

A perusal of the water level data reveals that the depth to water level ranged from **3.24 m bgl to 15 m bgl** . Depth to water level in the range of 0 to 5 m bgl has been recorded in **12 %** of wells analysed, 5 to 10 m bgl water level has been recorded in **48 %** of wells analysed and 10 to 15 m bgl water level has been recorded in **40 %** of wells analysed.

Post-Monsoon 2022 DTWL of Aq-I -(Fig-6B)

A perusal of the water level data reveals that the depth to water level ranged from **1.69 m bgl to 13.05 m bgl** . Depth to water level in the range of 0 to 5 m bgl has been recorded in **28 %** of wells analysed, 5 to 10 m bgl water level has been recorded in **67 %** of wells analysed and 10 to 15 m bgl water level has been recorded in **5 %** of wells analysed.

Table-7: Depth to water level of Pre-monsoon

Sr. No	Village	Source	Pre-monsoon Depth to water May-2022 (mbgl)	Post-monsoon Depth to water Nov-2022 (mbgl)	Seasonal Fluctuation
1	Airodi	Dug Well	7.5	3.20	4.3
2	Badamikatte	Dug Well	6.3	7.35	-1.05
3	Bantkal	Dug Well	10.7	9.13	0.42
4	Brahmavara	Dug Well	10.25	9.96	1.57
5	Goliangadi	Dug Well	10.65	8.75	1.9
6	Herady-Barkur	Dug Well	4.43	5.70	-1.27
7	Kodavuru	Dug Well	3.24	1.69	1.55
8	Kannangaaru	Dug Well	12.7	7.00	5.7
9	Karje	Dug Well	9.45	6.52	2.93
10	Katpadi	Dug Well	14.7	9.97	4.73
11	Kokkarne	Dug Well	9.44	6.00	3.44
12	Udupi	Dug Well	15	13.05	1.95
13	Koup Uliyargoli	Dug Well	10.02	8.16	1.86
14	Kukkehalli	Dug Well	11.05	8.65	2.4
15	Kunjaragiri Cross	Dug Well	9.62	8.45	1.17

16	Kaup	Borewell	9.44	8.11	1.33
17	Perduru BW	Borewell	13.95	9.37	4.58
18	Manipura BW	Borewell	9.30	7.88	1.42
19	Parkala BW	Borewell	8.60	8.87	-0.27
20	Udupi	Borewell	11	9.96	1.04
21	Bhramavara	Borewell	8.45	7.78	0.67
22	Haluvalli	Borewell	11.38	8.41	2.97

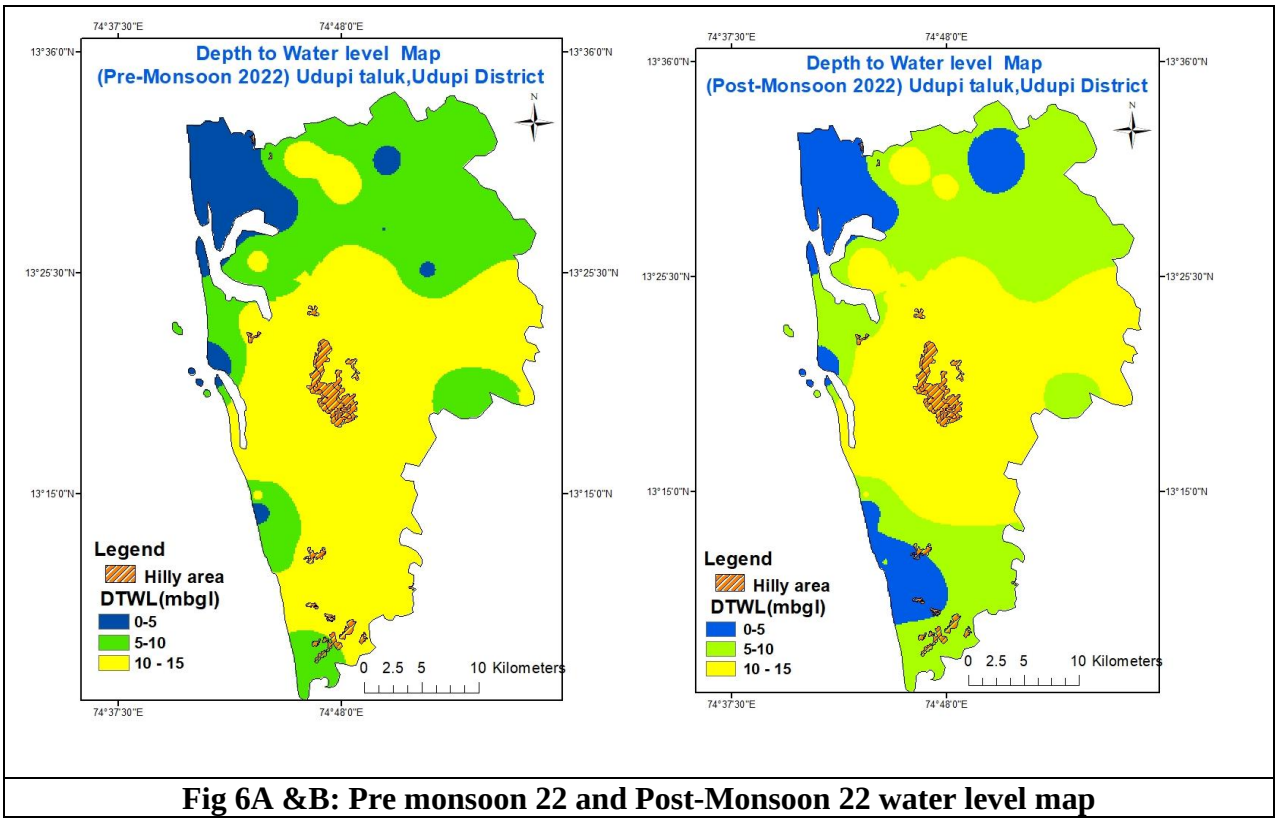


Fig 6A &B: Pre monsoon 22 and Post-Monsoon 22 water level map

B. DEPTH TO WATER LEVEL OF PIEZOMETRIC SURFACE:

The distribution of depth to water level of Fractured aquifer in different depth ranges is presented . Salient features of the depth to water level scenario during **May 2022** and **Nov 22** are given below**(Table-7).**

Pre-Monsoon 2022 DTWL of Aq-II-(Fig-6C)

A perusal of the water level data reveals that the depth to water level ranged from **3.65 m bgl to 14 m bgl** . Depth to water level in the range of 0 to 5 m bgl has been recorded in **30 %** of wells analysed, 5 to 10 m bgl has been recorded in **30 %** of wells analysed and more than 10 m bgl has been recorded in **40 %** of wells analysed.

Post-Monsoon 2022 DTWL of Aq-II -(Fig-6D)

A perusal of the water level data reveals that the depth to water level ranged from **3.5 m bgl to 13.08 m bgl** . Depth to water level in the range of 0 to 5 m bgl has been recorded in **20 %** of wells analysed, 5 to 10 m bgl water level has been recorded in **60 %** of wells analysed and more than 10 m bgl water level has been recorded in **20 %** of wells analysed.

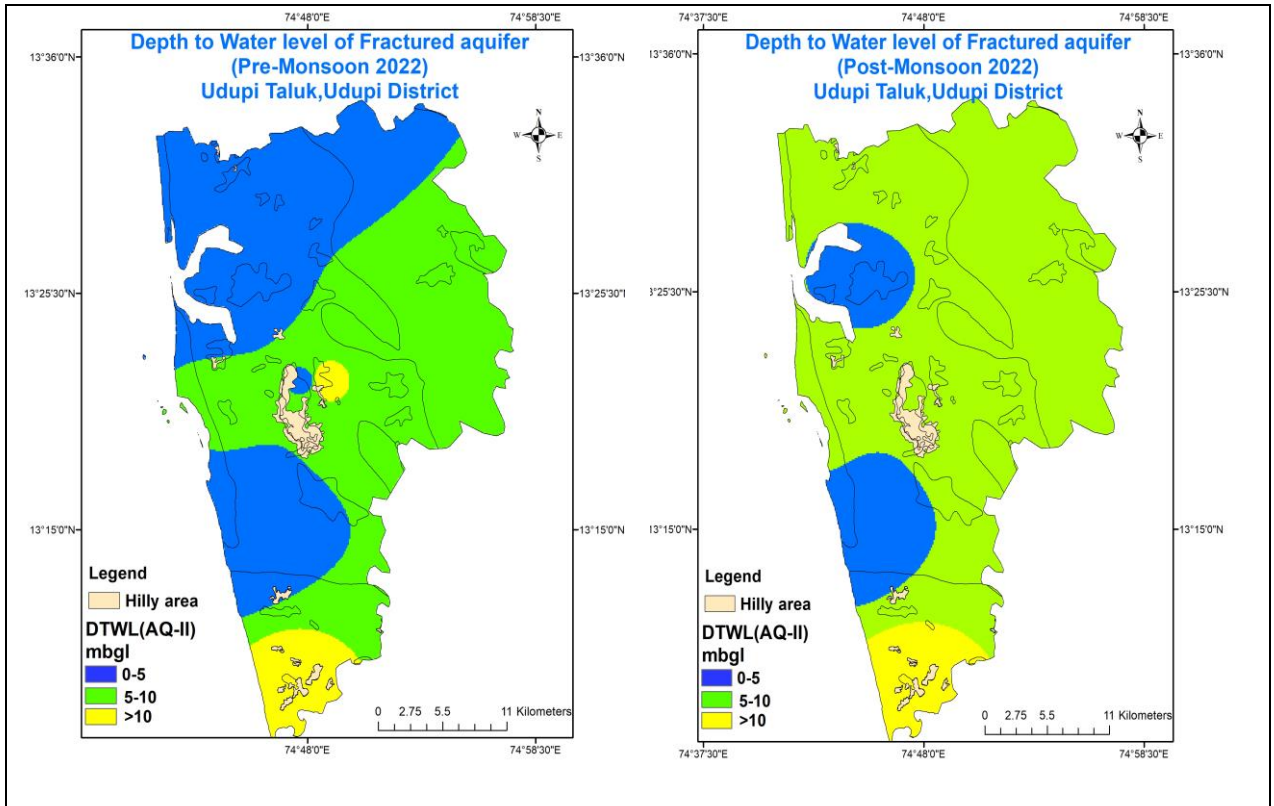


Fig 6C &D: Pre monsoon and Post-Monsoon 2022 Fractured water level map

C. SEASONAL FLUCUATION of Aq-I (May 2022-Nov2022) –

The distribution of ground water monitoring wells of Aq-I showing rising and falling in different ranges of fluctuation is presented. **(Fig-6E)**

Rise in the water level in the range of 0-2 m has been observed in **71%** of wells analysed, 2-5 m rise has been observed in **7%** of wells analysed, 5-10 m rise has been observed in **7%** of wells analysed and 10-15 m rise has been observed in **4%** of wells analysed. The fall in water level in the range of 0-2 m has been observed in **11%** of wells analysed.

SEASONAL FLUCUATION of Aq-II (May 2022-Nov2022) –

The distribution of ground water monitoring wells of Aq-II showing rising and falling in different ranges of fluctuation is presented. **(Fig-6F)**

Rise in the water level in the range of 0-2 m has been observed in **70%** of wells analysed and more than 2 m rise has been observed in **20%** of wells analysed. The fall in water level in the range of 0-2 m has been observed in **10%** of wells analysed.

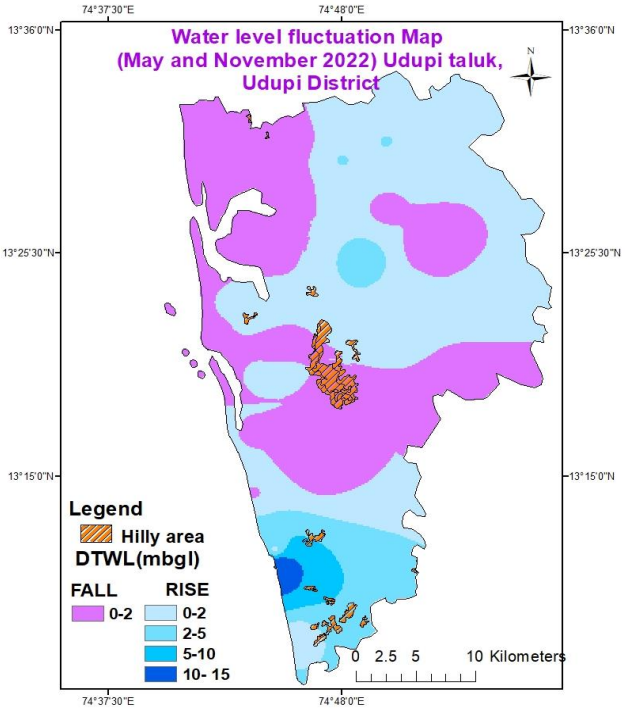


Fig-6E Seasonal Fluctuation Map of Udupi Taluk of Aquifer-I

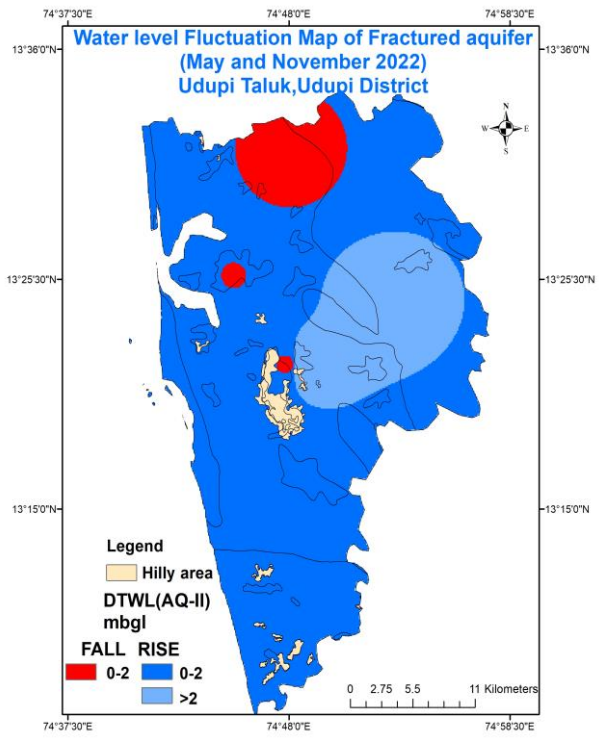


Fig-6F Seasonal Fluctuation Map of Udupi Taluk of Aquifer-II

C. ANNUAL FLUCTUATION OF PRE & POST MONSOON-

Annual Fluctuation of Pre-Monsoon (May 21 to May 22)-

The distribution of ground water monitoring wells falling in different ranges of fluctuation is showing in **Fig-6G**. A comparison of water level shows that a fall in the water level is recorded in 86 % of wells analysed, while 14 % recorded rise. Salient features of the comparison of water levels are given below.

Rise in the water level in the range of 0-1 m has been observed in **14%** of wells analysed. The fall in water level in the range of 0-2 m has been observed in **69%** of wells analysed and more than 2 m fall has been observed in **17 %** of wells analysed.

Annual Fluctuation of Post-Monsoon (Nov 2021 to Nov 22)-

The distribution of ground water monitoring wells falling in different ranges of fluctuation is showing in **Fig-6H**. A comparison of water level shows that a fall in the water level is recorded in 75 % of wells analysed, while 25 % recorded rise. Salient features of the comparison of water levels are given below.

Rise in the water level in the range of 0-2 m has been observed in **17 %** of wells analysed and more than 2 m rise has been observed in **8 %** of wells analysed. The fall in water level in the range of 0-2 m has been observed in **37%** of wells, 2-4 m fall has been observed in **32%** of wells and more than 4 m fall has been observed in **6%** of wells.

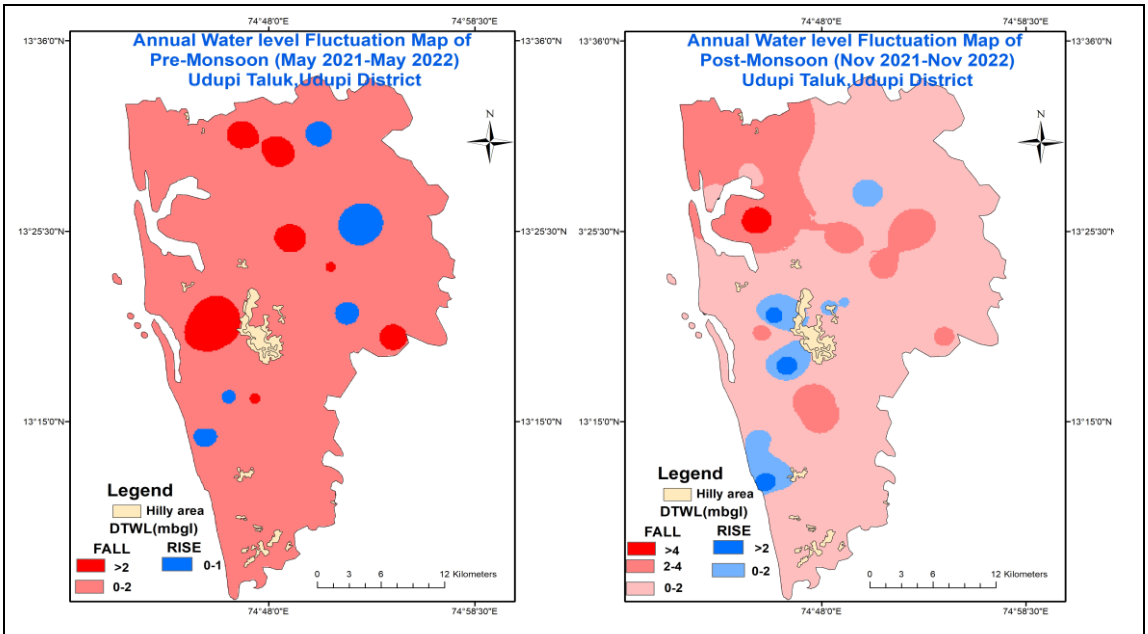


Fig 6G & H: Annual water level fluctuation Map of Pre monsoon & Post-Monsoon

D. DECADAL AVERAGE PRE & POST MONSOON—

Decadal average Pre-Monsoon (2013-2022) DTWL-

A perusal of the water level data reveals that the depth to water level ranged from **3.85 m bgl to 12.92 m bgl**. **(Fig-6I)** Depth to water level in the range of 0 to 5 m bgl has been recorded in **14 %** of wells analysed, 5 to 10 m bgl water level has been recorded in **60 %** of wells analysed and 10 to 15 m bgl water level has been recorded in **26 %** of wells analysed.

Decadal average Post-Monsoon (2013-2022) DTWL-

A perusal of the water level data reveals that the depth to water level ranged from **1.82 m bgl to 8.55 m bgl** . **(Fig-6J)** Depth to water level in the range of 0 to 2 m bgl has been recorded in **3 %** of wells analysed, 2 to 5 m bgl water level has been recorded in **26 %** of wells analysed and 5 to 10 m bgl water level has been recorded in **71 %** of wells analysed.

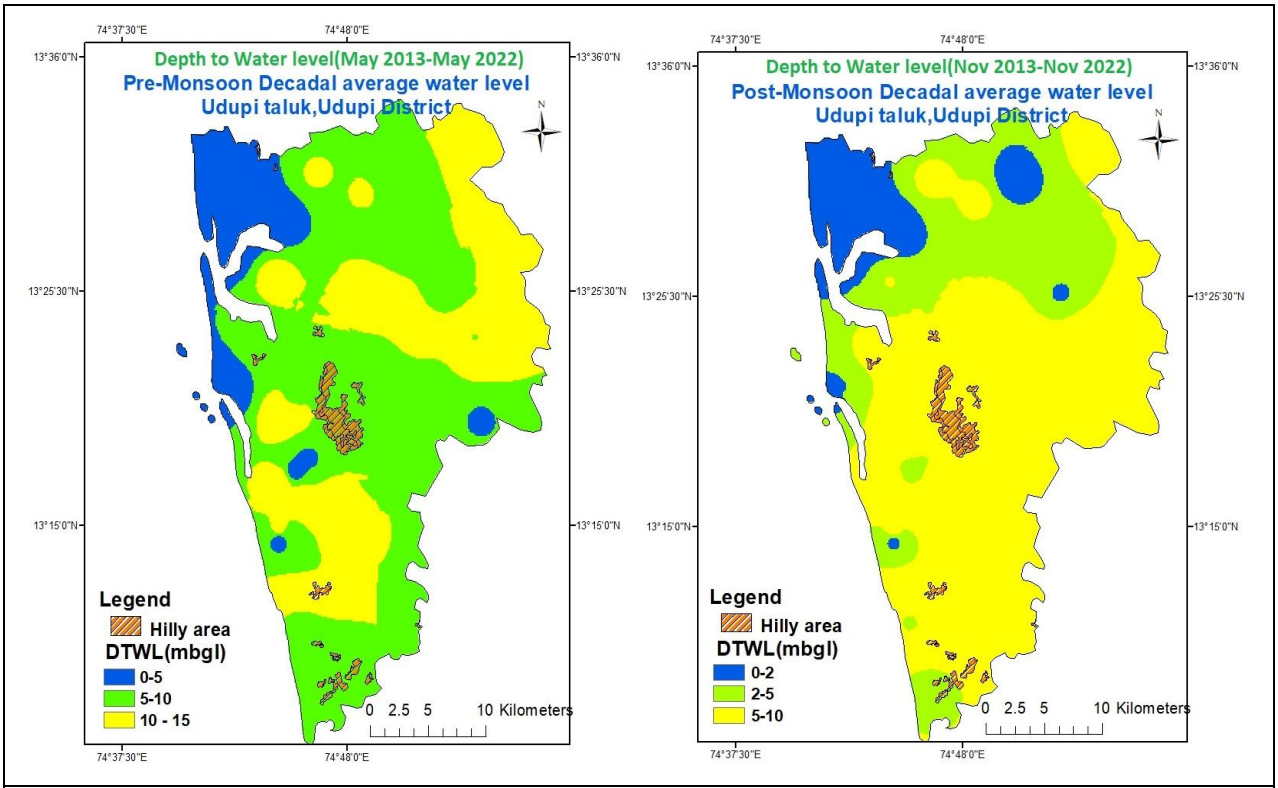


Fig 6I &J: Decadal average Pre Monsoon and Post-Monsoon water level map

E. DECADAL FLUCTUATION OF PRE & POST MONSOON-

Decadal Fluctuation of Pre-Monsoon (May 2012-21 to 22)-

The distribution of ground water monitoring wells falling in different ranges of fluctuation is showing in **Fig-7**. A comparison of water level shows that a fall in the water level is recorded in 49 % of wells analysed, while 51 % recorded rise. Salient features of the comparison of water levels are given below.

Rise in the water level in the range of 0-2 m has been observed in **37%** of wells analysed, 2-5 m rise has been observed in **5%** of wells analysed and 5-10 m rise has been observed in **9%** of wells analysed. The fall in water level in the range of 0-2 m has been observed in **35%** of wells analysed and 2-5 m fall has been observed in **14%** of wells analysed.

Decadal Fluctuation of Post-Monsoon (Nov 2012-21 to 22)-

The distribution of ground water monitoring wells falling in different ranges of fluctuation is showing in **Fig-8**. A comparison of water level shows that a fall in the water level is recorded in 87 % of wells analysed, while 13 % recorded rise. Salient features of the comparison of water levels are given below.

Rise in the water level in the range of 0-2 m has been observed in **5 %** of wells analysed, 2-4 m rise has been observed in **5 %** of wells analysed and more than 4 m rise has been observed in **3%** of wells analysed. The fall in water level in the range of 0-2 m has been observed in **28%** of wells analysed and 2-4 m fall has been observed in **47%** of wells analysed and more than 4 m fall has been observed in **12%** of wells analysed.

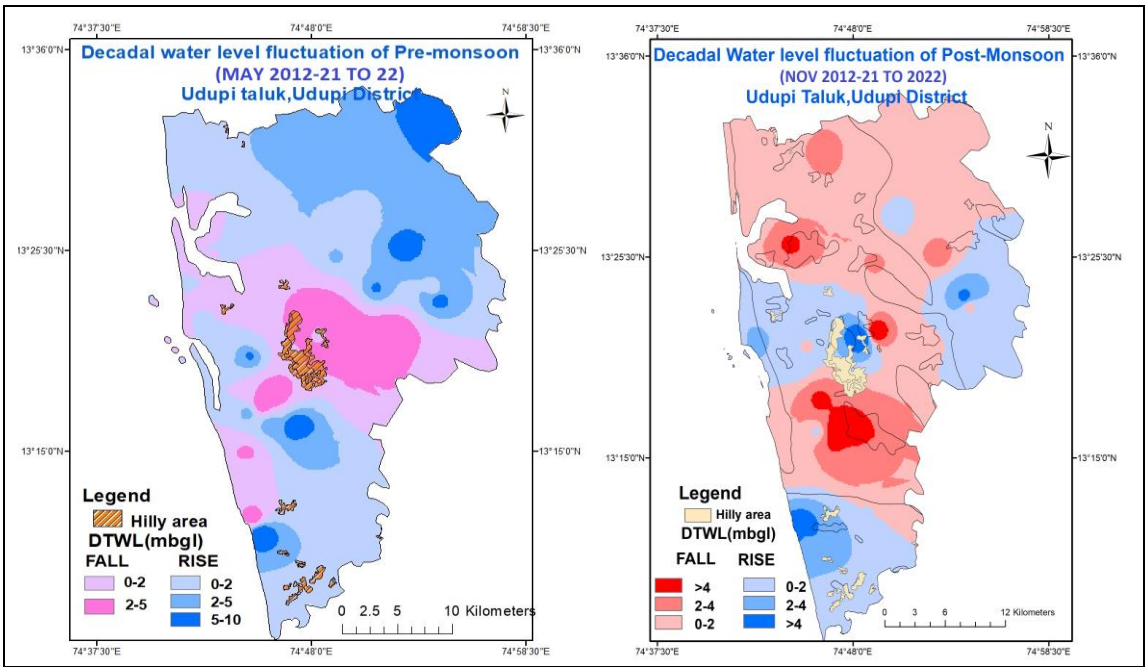
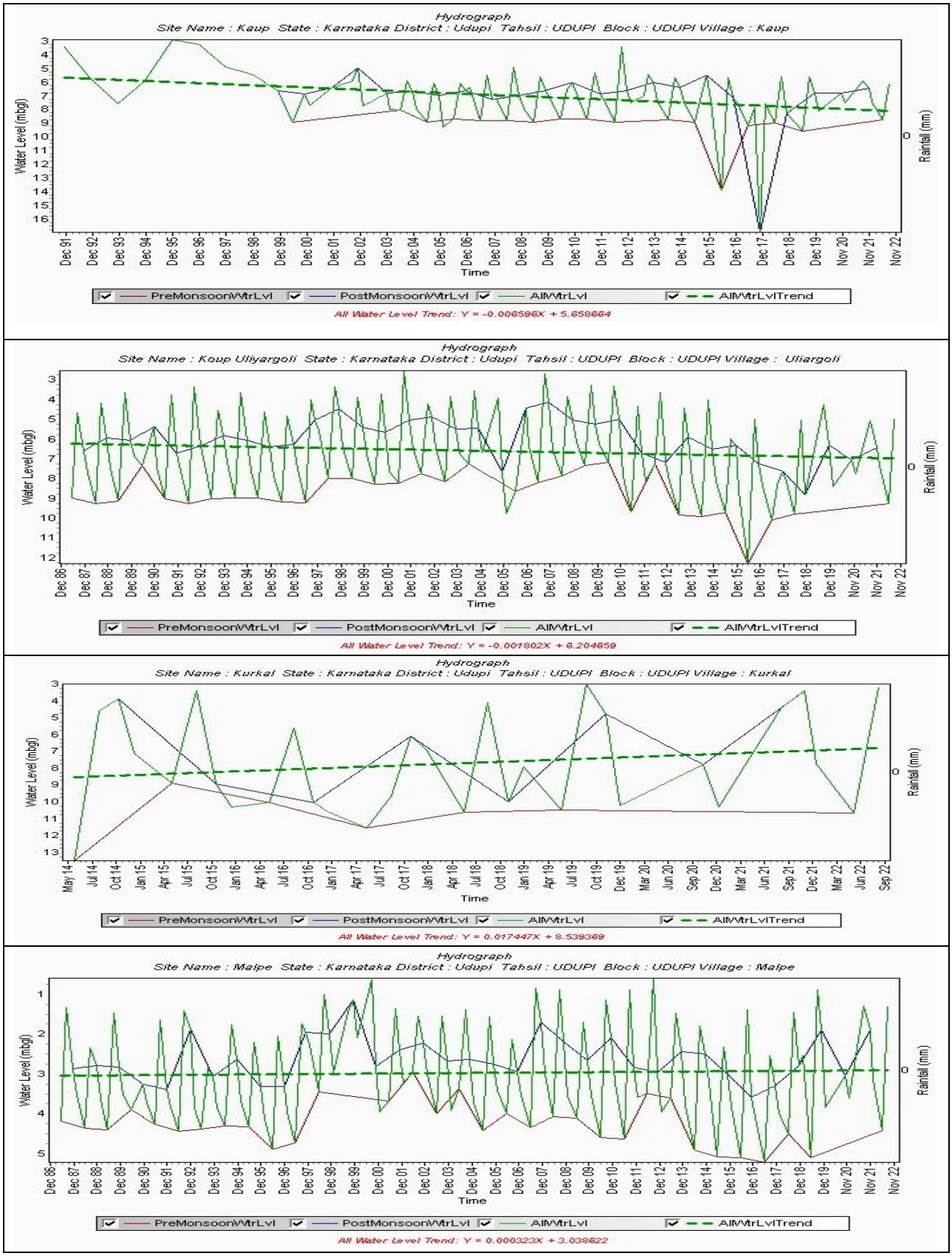


Fig 7 & 8: Decadal water level fluctuation Map of Pre monsoon & Post-Monsoon

F. Long term water level trend & Hydrographs of Udupi taluk-



2 AQUIFER DISPOSITION

Banded Gniessic Complex occupy nearly 80% of all over the taluk whereas alluvium occurs in the rest 10% in the western part of the Taluk **(Fig 8)** and laterite is mostly in all portion of taluk.The gneisses comprise of migmatites associated with biotites and hornblendes. The granites are grey in colour and are fine to coarse grain in nature. Ground water occurs under water table to semi confined condition depending upon disposition of aquifer which is mainly granite and schist. Ground water occur under water table to semi confined condition in granite whereas in schist groundwater occur in weathered, jointed and fractured zone under water table condition.

Ground water exploration programme of CGWB was carried out in one phases in the taluk. There are few wells have been drilled in Udupi Taluk, which reveals that the weathered, jointed and fractured granite is the potential aquifer system.

Majority of the dug well in granitic gneiss ranges in depth from **12m to 30.48m** having a weathered zone from **5 m to 29m**. Water level lies in the range of **3.24 m bgl to 15 mbgl**.

Pumping test of 500 minutes conducted on open well in Udupi have revealed that the discharge ranges between **0.1 to 6.6 lps** with a drawdown of 18.91 m and unit area specific capacity of **20.56 lpm/m/m**.

2.1 Number of aquifers:

In Udupi Taluk, there are mainly two types of aquifer systems;

i. Aquifer-I (Phreatic aquifer, weathered zone) comprising of **Granitic Gneiss**

ii. Aquifer-II (Fractured zone) comprising of **Fractured Granitic gneiss**

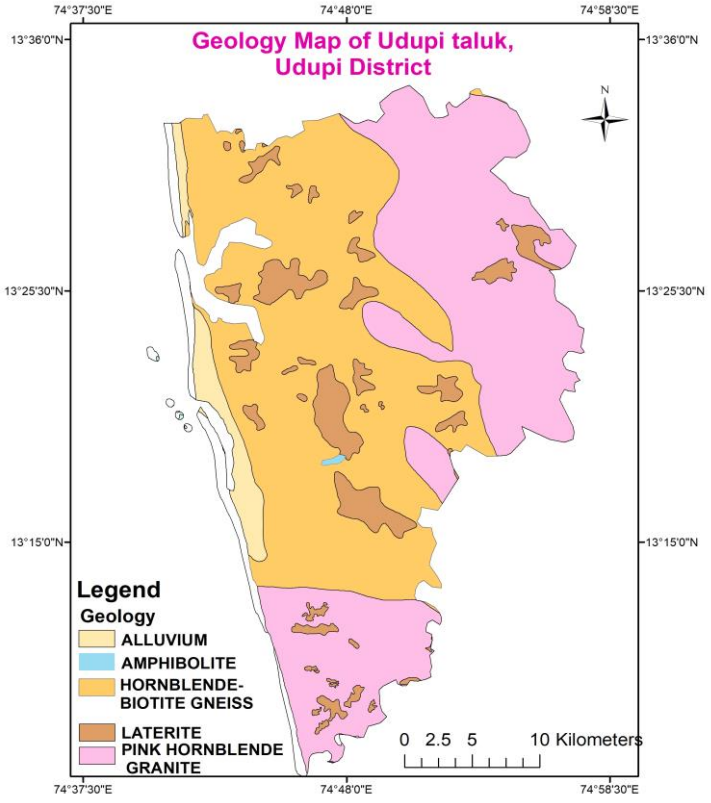


Fig 9: Geology Map

Fig 9 showing the Geology of Udupi taluk, Hornblende biotite gniess is found most of the central part of taluk, alluvium in western part of taluk in Coastal area, laterite found in patches in almost all part of taluk and Pink Hornblende granite in Eastern and Southern part of taluk.

Table-8: Details of Ground Water Exploration

S. No	Location	Lat	Long	Depth m bgl	Casing (m)	Litholo gy	SWL (mbgl)	Q (lps)	T (m^2/day)
1	Manipura	13.2945	74.7737	175	15	Granite	-	0.1	-
2	Onthibettu	13.347	74.8506	166	17	Granite	-	0.4	-
3	Kuladi kanthu Colony	13.3284	74.8892	141	36	Granite	-	3.6	-
4	Pragathinagar	13.3158	74.7957	182	25	Granite	-	0.2	-
5	J.N Nagara Durganagara	13.2945	74.7358	140	33	Granite	-	0.3	-
6	Bairampalli	13.3618	74.9379	181	25	Granite	-	3.6	-
7	Kotibettu	13.3163	74.8967	199	25	Granite	-	0.26	-
8	Pernakila	13.2962	74.8495	199	27	Granite	-	0.3	-
9	Athrady	13.3516	74.8258	182	23.78	Granite	-	3.6	-
10	Punchur	13.3986	74.8195	202	23.78	Granite	-	0.3	-
11	Adapady	13.4001	74.8863	115.85	29.26	Granite	-	2	-
12	Salmara	13.3722	74.7574	182.92	25	Granite	-	0.6	-
13	Haluvalli	13.4063	74.8678	121.95	14.63	Granite	-	3.6	-
14	Uppur	13.396	74.7395	156.09	23.17	Granite	-	2	-
15	Tenkanidyoor	13.3662	74.7134	134.75	30.48	Granite	-	2	-
16	Alevoor	13.3888	74.725	182.92	6.09	Granite	-	0.12	-
17	Baikady- EW	13.41667	74.725	226.3	6	ARCN GRNT	6.03	6.66	15
18	Kenjoor	13.4256	74.9236	150.13	17	ARCN GRGN	7.56	Negl	4
19	Kudigrama- EW	13.31692	74.86967	67.3	25.06	ARCN GRNT ACID INTRUSI VE	6.203	5.5	78
20	Malpe EW	13.36759	74.69904	15.5	5	RECENT ALVM	1.185	3.6	7
21	Perdur Putage	13.39228	74.90483	50.06	9.22	ARCN GRGN	3.07	0.31	-
22	Varampalli	13.41	74.7131	61.5	16.6	ARCN GRGN	4.613	3.75	34.8

Table-9 Basic characteristics of each aquifer

Aquifers	Weathered Zone (Aq.-I)	Fractured Zone (Aq.-II)
Prominent Lithology	Weathered Gniess/Schist	Fractured Gniesses/Schist
Thickness range (mbgl)	30.48	Fractures upto 226.3 mbgl
Depth range of occurrence of fractures (mbgl)	5-29	25-185
Range of yield potential (lps)	Poor yield	1-6.6
Specific Yield	2%	0.2%
T (m^2/day)	-	7-78
Quality Suitability for Domestic &Irrigation	Suitable	Suitable

2.2 Depth wise Aquifer System

The data generated from ground water monitoring wells, hydrogeological inventories, exploratory and observation wells, various thematic layers was utilized to decipher the aquifer disposition of the area. In the taluk, if we consider the vertical distribution of aquifer, two types of aquifer system are observed i.e., Aquifer – I which is a shallow phreatic aquifer and Aquifer – II which constitutes the deeper fractured aquifer.

2.2.1 Aquifer-I (Shallow Phreatic aquifer)

Aquifer – I comprises of Alluvium,Laterite and weathered granitic gneiss. The spatial distribution of depth of occurrence and aquifer thickness of Aquifer-I is depicted in **Fig. 9A** and the hilly area, Drainage map and borewell location is also included in map. It indicates that the depth of occurrence of aquifer – I ranges from 6 to 35 m bgl. However, it mainly occurs in the depth range of 20 to 25 m bgl covering 60% of the area in central and eastern part of the taluk. The depth of occurrence of 6 to 15 m bgl is observed in about 1% of area mainly in patches in all parts of the taluk. 25-35 m depth occurred in patches in 5%. The depth of occurrence of 15 to 20 m bgl is observed in about 34% in the Northern to southern part of taluk.

The perusal of the map for aquifer thickness indicates that it ranges from 4 to 16 m, however aquifer thickness of 4 to 8 m is observed in about 70% of the area covering all part of the taluk in patches. The aquifer thickness of 8 to 10 m is observed in 20% of the areas in patches covering all parts of taluk. The maximum thickness of 10 to 16 m observed in 10% mostly in Eastern, western and southern part of taluk.

2.2.2 Aquifer-II (Deeper Fractured aquifer)

It comprises of Alluvium, ambhibolite laterite and fractured Granite Gneiss rock. The spatial distribution of depth of occurrence and aquifer thickness of Aquifer-II is depicted in **Fig. 9B** and the hilly area, Drainage map and borewell location is also included in map. It indicates that the depth of occurrence of aquifer – II ranges from 95 to 200 m bgl. However, it mainly occurs in the depth range of 145 to 155 m bgl covering 60% of the area in Northern, western and southern part of the taluk. The depth of occurrence of 95 to 130 m bgl is observed in about 5% in patches in western and eastern part of taluk. The depth of Occurrence of 130-145 is observed in 5% in Western and Eastern part of taluk. 155-165 m observed in Central and eastern part. The deeper depth of occurrence of 165 to 200 is observed in 10% in Central and eastern part of taluk. The perusal of the map for fractured aquifer thickness indicates that it ranges from 6 to 18 m, however aquifer thickness of 6 to 8 m is observed in about 60% of the area covering central and eastern parts of the taluk. The aquifer thickness of 8 to 12 m is observed in 30% of the areas covering western and northern parts. The higher fractured aquifer thickness of 12-18 m is observed in Northern part of taluk.

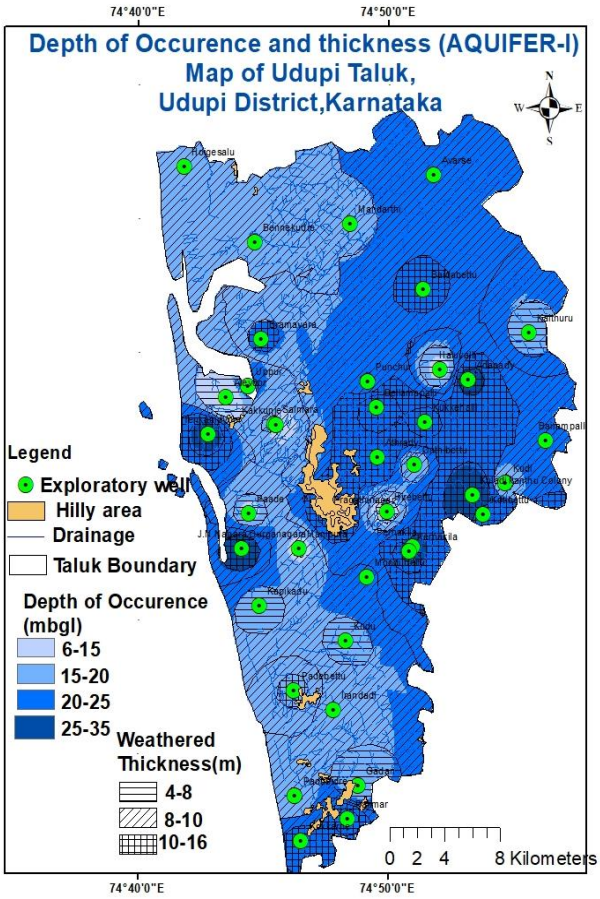


Fig-9A Depth of Occurrence and thickness Map (Aq-I)

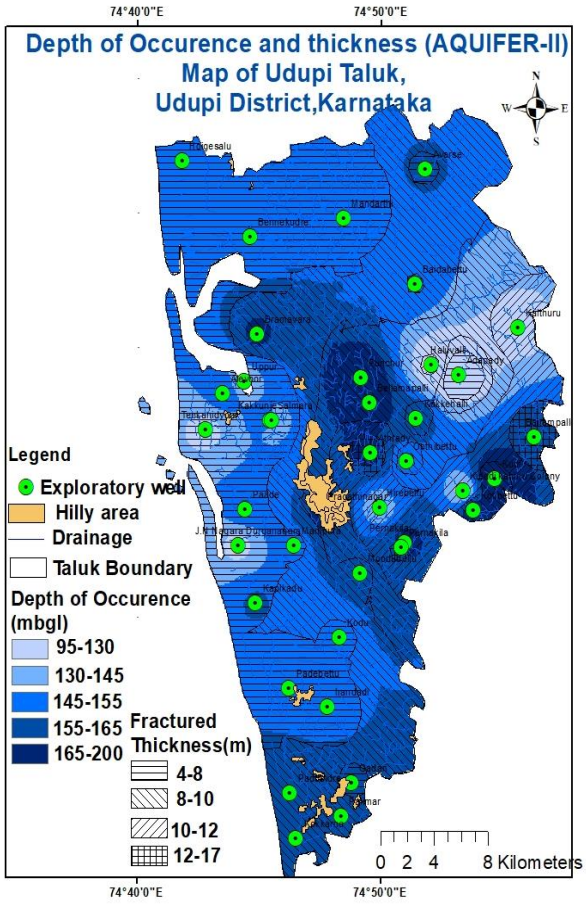


Fig-9B Depth of Occurrence and thickness Map (Aq-II)

2.3 3 D aquifer disposition and Cross-Sections

Aquifer disposition – The drilling data obtained from other departments is utilised for generating aquifer disposition maps through Rock works software. The **2D** and **3D** outputs thus obtained is presented in **Fig-10,Fig-11 & to Fig-12.**

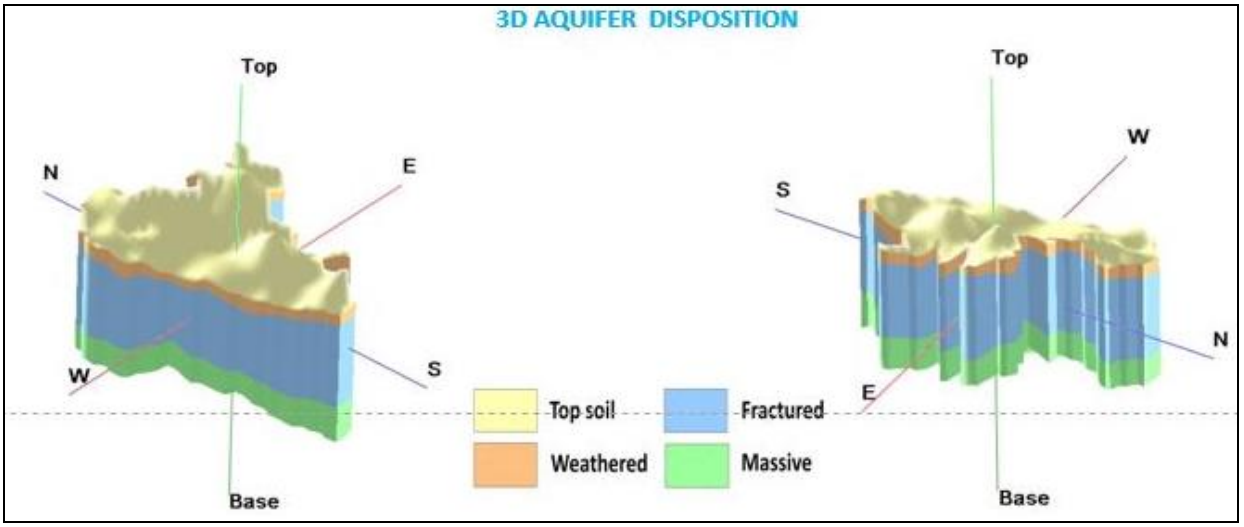


Fig-10: 3D aquifer Disposition

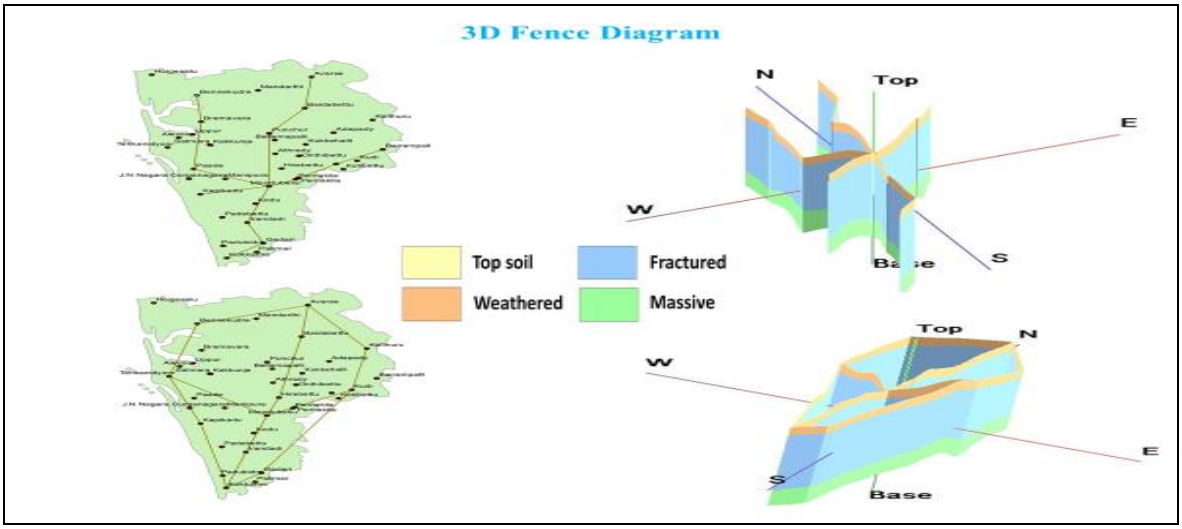


Fig-11: 3D Aquifer Fence Diagram

The fence diagram indicating the disposition of various aquifers is presented in **Fig.-11**. In Western & Southern part of the taluk, the laterite present at top followed by Pink Hornblende granite, whereas in the Central and eastern part,the Hornblende biotite granite is present below laterite and in Coastal part, alluvium is present.The 3-D representation is presented in **Fig.-10**. The disposition of Aquifer-I and Aquifer-II followed by massive formation can be observed in the 3-D aquifer disposition. The depth of the top soil is in the range of 0 to 5 m bgl, followed by weathered aquifer observed upto 30 m, which is followed by fractured aquifer which is disposed upto 185 m bgl depth followed by massive formation devoid of any ground water.

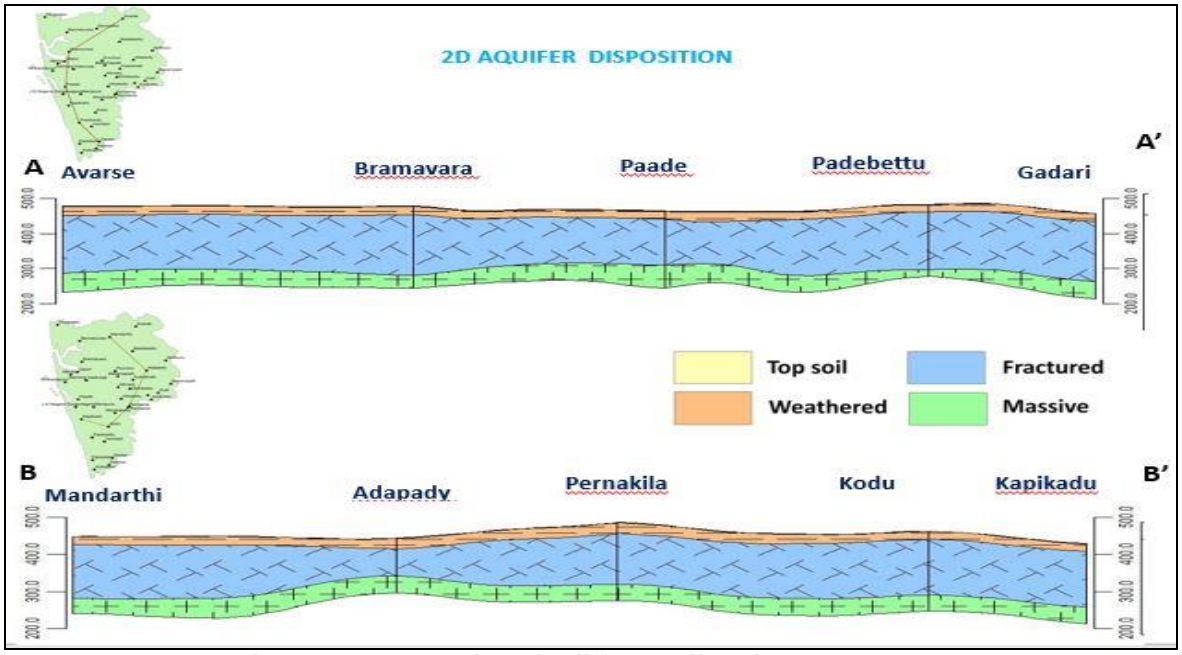


Fig-12: Cross sections in different directions

To study the aquifer disposition in detail, various hydrogeological cross section indicating aquifer geometry has been prepared viz. A-A' representing NE–SW direction, B-B' representing NW-SE direction respectively.**(Fig-12)**

Hydrogeological cross section A-A' (**Fig.-12**) represents NW-SE direction and data of 37 exploratory wells has been utilised. It can be clearly seen from the NW-SE direction i.e., from Avarse to Gadari, the thickness of Aquifer-I (shallow aquifer) and Aquifer-II (deeper aquifer) is same and the thickness of Massive rock is also same from A to A'.

Hydrogeological cross section B-B' (**Fig.-12**) represents NE–SW direction and data of 37 exploratory wells has been utilised. It can be clearly seen from the section from NE–SW direction, from Mandarthi to Kadikadu, the thickness of Aquifer-I (shallow aquifer) and Aquifer-II (deeper aquifer) is same. On the contrary, the thickness of Massive rock is more in B and less in B'.

2.4 Hydrogeology of Phreatic and Fractured aquifer:-

Majority of the dug well in granitic gneiss ranges in depth from **12m to 30.48m** having a weathered zone from **5 m to 29m**. Discharge of well is almost <1 lps. Transmissivity is very less and Water level lies in the range of **3.24 m bgl to 15 m bgl**.

0-10 m **weathered thickness** found in western part of taluk, 10-20m thickness found in western and eastern part of taluk, 20- 30m found from Northern to Southern part of taluk and 30- 35m found in patches in Western and eastern part of taluk**. (Fig-13)**

Bore well in Fractured granitic gneiss ranges in depth upto **200 m** having a weathered zone from **6 m to 36 m** and Fractured zone from **25 to 185 mbgl**. Transmissivity of the Mangalore taluk is **7-78 m2/day**, Discharge ranges between **0.1 to 6.6 lps** with a drawdown of **18.91 m** and unit area specific capacity of **20.56 lpm/m/m.**

Hydrogeology Map of Udupi taluk showing that Hornblende biotite gniess is found most of the central part of taluk, alluvium in western part of taluk in Coastal area, laterite found in patches in almost all part of taluka and Pink Hornblende granite in Eastern and Southern part of taluk. Yield of the taluk revealed that <1 lps found in Northern & Southern part of taluk, 1-3 lps in Eastern & Western taluk and >3 lps

found in some patches in Western and eastern which show high yielding of the taluk. Lineament found in Eastern part of taluk. **(Fig-14)**

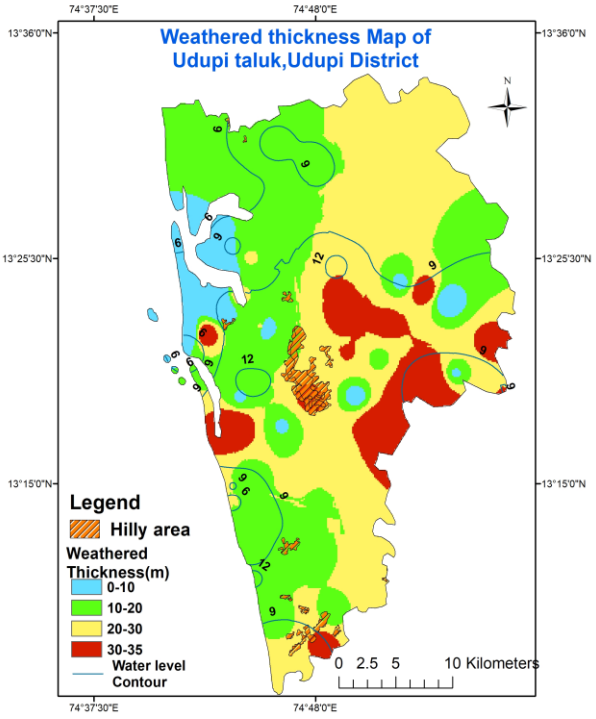


Fig-13 Weathered Map of Udupi Taluk

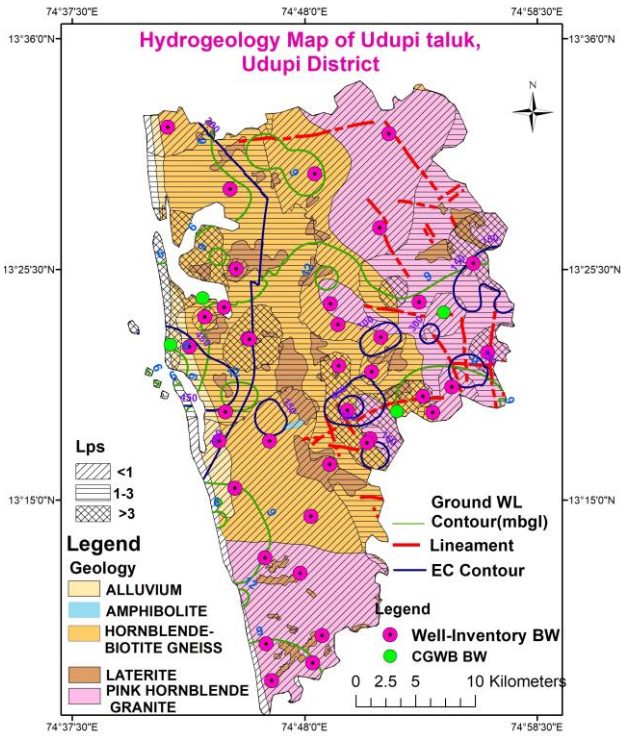


Fig-14 Hydrogeology Map of Udupi Taluk

3 GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES

3.1 Aquifer wise resource availability and extraction (2022)

Taluk	Annual Extract GW resource (ham)	Existing Gross GW extraction for Irrigation (ham)	Existing Gross GW extraction for domestic and industrial water supply (ham)	Existing Gross GW extraction for all uses (ham)	Allocation for domestic and industrial use for the next 25 years (ham)	Net GW availability for future Irrigation development (ham)	Stage of GW development (%)	Category
Udupi	14262.84	4545.41	1104.67	5650.09	1127.7	8579.54	39.6	**Safe**

Table-10 Comparison of ground water availability and draft scenario in Udupi taluk

Taluk	2017			2020			2022		
	GW Availability	GW Draft	Stage of GW withdrawal	GW Availability	GW Draft	Stage of GW withdrawal	GW Availability	GW Draft	Stage of GW withdrawal
Udupi	9515	4310	**45**	18796	4935	**26.3**	14262.84	5650.09	**39.6**

From the above comparison**(Table-10),** it can be observed that the stage of ground water extraction is more during 2017 and less in 2020 and again the stage of ground water extraction increases in 2022.

3.2 Chemical quality of ground water and contamination

The interpretation from Chemical Analysis results (Phreatic and fractured aquifer) of ground water samples in Udupi taluk is summarized below. The results are presented in **Figures wise..**

(a) Aquifer – I: 28 samples were collected from NHS dug wells representing **Aquifer – I** in Udupi Taluk and chemical analysis result indicate that the-

EC value is in the ranges of 105 to 450 m/mhos/cm at 25°C. All the sample shows under desirable limit**. (Fig-15)** The value of **pH** ranges from 6.10 to 7.78. **Cl** ranges from 11 mg/l to 110 mg/l. **(Fig-16)** The value of **NO_3** ranges from 1 to 41 mg/l. All the sample shows under desirable limit as per BIS, 2012 drinking water standards. **(Fig-17)** All the samples show **fluoride** within desirable limit as per BIS, 2012. **(Fig-18)**

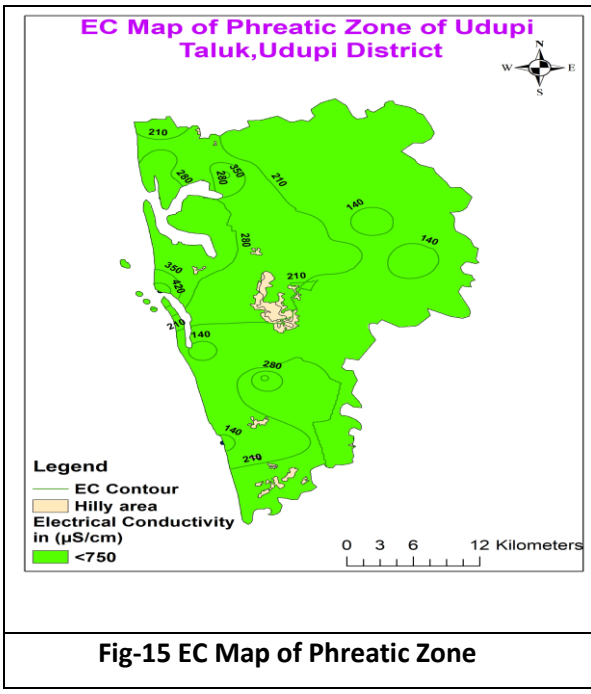


Fig-15 EC Map of Phreatic Zone

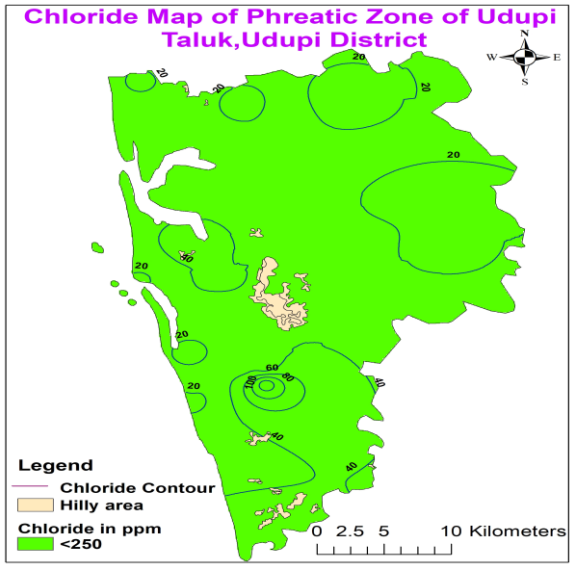


Fig-16 Chloride Map of Phreatic Zone

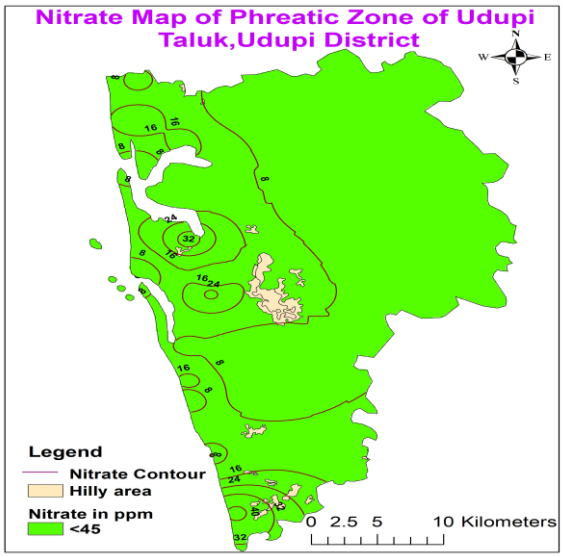


Fig-17 Nitrate Map of Phreatic Zone

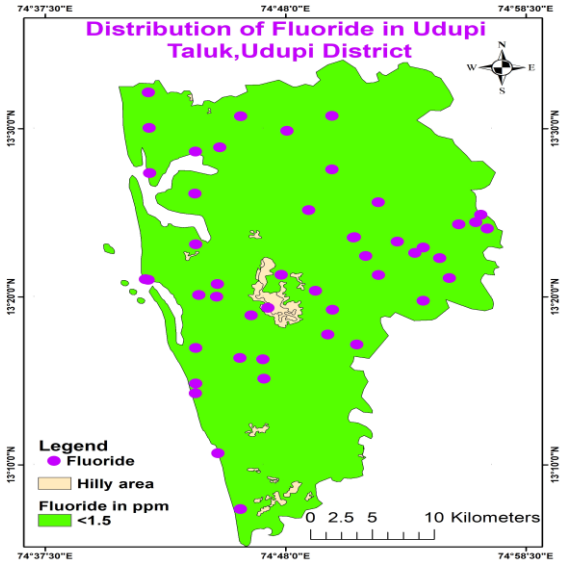


Fig-18 Distribution of Fluoride

(b) Aquifer -II: 20 samples were collected from borewells and Hand pump which represented the **aquifer II** in Udupi Taluk.

EC value in groundwater is in the ranges of 50 to 590 m/mhos/cm at 25°C. All the sample shows under desirable limit. **(Fig-19)** The value of **pH** ranges from 5.8 to 8.

Cl ranges from 4 mg/l to 82 mg/l. **(Fig-21)** The value of **NO_3** ranges from 5 to 14 mg/l. All the sample shows under desirable limit as per BIS, 2012 drinking water standards. **(Fig-20)** All the samples show **fluoride** value within desirable limit as per BIS, 2012 standards. **(Fig-18)**

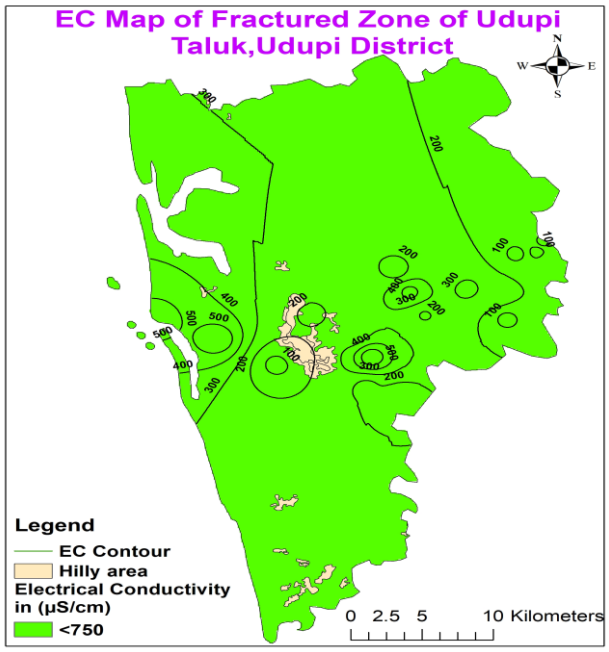


Fig-19 EC Map of Fractured Zone

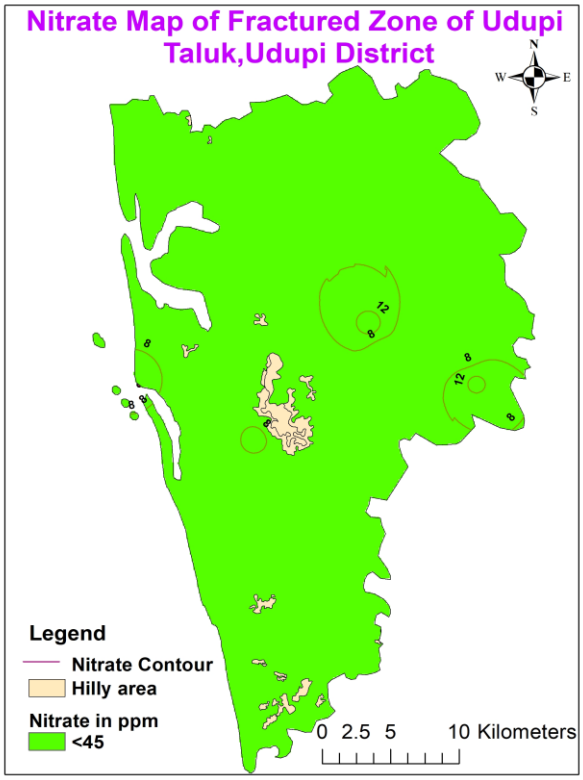


Fig-20 Nitrate Map of Fractured Zone

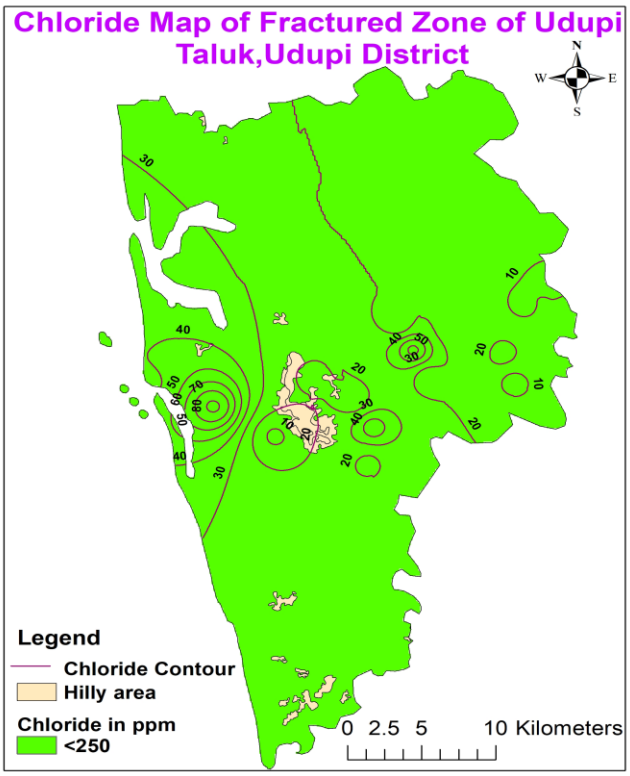


Fig-21 Chloride Map of Fractured Zone

In general, ground water quality in Udupi Taluk is good and potable and are found to be under permissible limit. Ground water samples have been found suitable for agriculture & irrigation purposes.

4 GROUND WATER RESOURCE ENHANCEMENT

4.1 Artificial recharge and proposed interventions

Increase in agricultural activity and excessive ground water withdrawal has resulted in depletion of ground water table, reduction in yield of bore wells and deterioration of ground water quality. Udupi Taluk can be drought prone. Thus, there is need for ground water management, enhancement of storage capacity of aquifers, protection of ground water quality and proper utilization of ground water.

Aquifer wise space available for recharge and proposed interventions

Table 11A: Quantity of water proposed to be made available through non-committed surface runoff

Non committed monsoon runoff available **(MCM)**	70.802
Artificial Recharge Structures Proposed	
Area feasible for artificial recharge structures (sq. km)	905
Number of Check Dams feasible	341
Number of Percolation Tanks feasible	64
Number of Point Recharge structures feasible	13
Tentative total cost of the project (Rs. in lakhs)	4724.264
Recharge capacity of sub surface dyke (MCM)	10.620
Recharge capacity of percolation tank (MCM)	35.401
Recharge capacity of Check dam (MCM)	17.700
Recharge capacity of filter bed (MCM)	7.080
Excepted recharge (MCM)	**53.101**

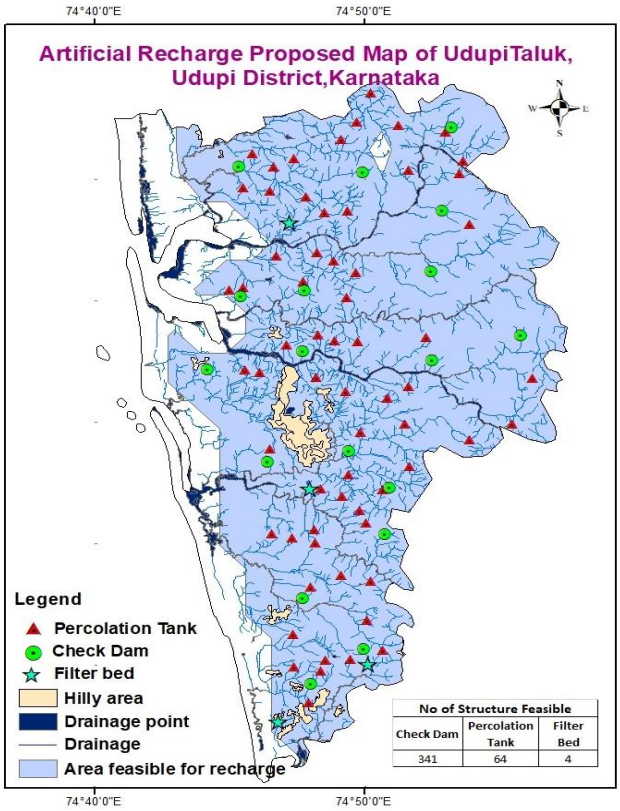


Fig-22 Artificial Recharge structure Proposed Map

Table:11B Tentative location of Villages for Proposal of Artificial Recharge structure

S.N	Village	AR Structure	Longitude	Latitude
1	Phalimaru	Check Dam	74.79658	13.12137
2	Phalimaru	Check Dam	74.81948	13.12565
3	Nadssalu	Check Dam	74.77814	13.12743
4	Nandhikuru	Check Dam	74.80414	13.13087
5	Padhebettu	Check Dam	74.78277	13.14484
6	Padhebettu	Check Dam	74.77834	13.14826
7	Elluru	Check Dam	74.80043	13.15646
8	Nandhikuru	Check Dam	74.80937	13.15788
9	Santhuru	Check Dam	74.82197	13.15841
10	Padhebettu	Check Dam	74.78409	13.15878
11	Santhuru	Check Dam	74.84567	13.16057
12	Elluru	Check Dam	74.81244	13.16071
13	Elluru	Check Dam	74.79936	13.16235
14	Santhuru	Check Dam	74.82201	13.16312
15	Santhuru	Check Dam	74.83320	13.16671
16	Santhuru	Check Dam	74.83896	13.16837
17	Elluru	Check Dam	74.80070	13.16857
18	Thenka	Check Dam	74.78389	13.16858
19	Santhuru	Check Dam	74.84919	13.17110
20	Pilaru	Check Dam	74.82264	13.17701

21	Elluru	Check Dam	74.81044	13.17732
22	Pilaru	Check Dam	74.83287	13.17750
23	Elluru	Check Dam	74.78585	13.17779
24	Elluru	Check Dam	74.79476	13.17923
25	Elluru	Check Dam	74.77911	13.18230
26	Elluru	Check Dam	74.78795	13.18256
27	Belpu	Check Dam	74.77907	13.19297
28	Pilaru	Check Dam	74.84760	13.19305
29	Pilaru	Check Dam	74.83433	13.19464
30	Belpu	Check Dam	74.78847	13.19471
31	Pilaru	Check Dam	74.83616	13.19671
32	Pilaru	Check Dam	74.82850	13.19686
33	Belpu	Check Dam	74.76708	13.19755
34	Pilaru	Check Dam	74.85111	13.19894
35	Pilaru	Check Dam	74.83377	13.20275
36	Kalthuru	Check Dam	74.79176	13.20471
37	Belpu	Check Dam	74.76459	13.20503
38	Pilaru	Check Dam	74.83852	13.20546
39	Kuthyaru	Check Dam	74.82414	13.20551
40	Kalthuru	Check Dam	74.79457	13.21195
41	Shirva	Check Dam	74.82002	13.21411
42	Shirva	Check Dam	74.84337	13.21603
43	Mallaru	Check Dam	74.76096	13.21610
44	Shirva	Check Dam	74.84224	13.21831
45	Shirva	Check Dam	74.82597	13.21954
46	Padhuru	Check Dam	74.80982	13.21994
47	Padhuru	Check Dam	74.78205	13.22249
48	Shirva	Check Dam	74.80923	13.22528
49	Shirva	Check Dam	74.85008	13.22754
50	Shirva	Check Dam	74.84704	13.23020
51	Shirva	Check Dam	74.83603	13.23351
52	Shirva	Check Dam	74.82776	13.23533
53	Shirva	Check Dam	74.82337	13.23603
54	Heruru	Check Dam	74.79558	13.23793
55	Shirva	Check Dam	74.81464	13.23988
56	Shirva	Check Dam	74.84796	13.24193
57	Shirva	Check Dam	74.83546	13.24214
58	Shirva	Check Dam	74.81394	13.24621
59	Shirva	Check Dam	74.78337	13.24673
60	Shirva	Check Dam	74.85254	13.24691
61	Innanje	Check Dam	74.77484	13.24934
62	Shirva	Check Dam	74.84866	13.25094
63	Shirva	Check Dam	74.82402	13.25150
64	Shirva	Check Dam	74.84037	13.25179
65	Shirva	Check Dam	74.84762	13.25630
66	Belle	Check Dam	74.79835	13.25740
67	Kattangeri	Check Dam	74.82784	13.25887

68	Kurkalu	Check Dam	74.78652	13.26083
69	Kurkalu	Check Dam	74.77265	13.26183
70	Kattangeri	Check Dam	74.82368	13.26400
71	Belle	Check Dam	74.80894	13.26427
72	Kurkalu	Check Dam	74.78165	13.26496
73	Kattangeri	Check Dam	74.82606	13.26951
74	Kattangeri	Check Dam	74.83614	13.27032
75	Belle	Check Dam	74.80219	13.27240
76	Belle	Check Dam	74.81833	13.27288
77	Kattangeri	Check Dam	74.84807	13.27753
78	Kattangeri	Check Dam	74.83254	13.27786
79	Pernamkila	Check Dam	74.85713	13.27797
80	Kurkalu	Check Dam	74.78935	13.27817
81	Kurkalu	Check Dam	74.78476	13.27881
82	Belle	Check Dam	74.81265	13.27989
83	Kattangeri	Check Dam	74.84187	13.27999
84	Belle	Check Dam	74.82330	13.28223
85	Belle	Check Dam	74.80070	13.28251
86	Pernamkila	Check Dam	74.83826	13.28537
87	Kurkalu	Check Dam	74.76921	13.28739
88	Marni	Check Dam	74.83287	13.28780
89	Manipura	Check Dam	74.78194	13.28883
90	Pernamkila	Check Dam	74.84913	13.28901
91	Belle	Check Dam	74.79806	13.29064
92	Pernamkila	Check Dam	74.85738	13.29091
93	Pernamkila	Check Dam	74.86765	13.29315
94	Manipura	Check Dam	74.82449	13.29383
95	Pernamkila	Check Dam	74.84337	13.29420
96	Manipura	Check Dam	74.80947	13.29509
97	Pernamkila	Check Dam	74.85005	13.29562
98	Pernamkila	Check Dam	74.85528	13.29666
99	Manipura	Check Dam	74.78898	13.29746
100	Pernamkila	Check Dam	74.86498	13.29752
101	Pernamkila	Check Dam	74.86089	13.29845
102	Pernamkila	Check Dam	74.84567	13.29880
103	Pernamkila	Check Dam	74.84157	13.30088
104	Alevuru	Check Dam	74.78272	13.30247
105	Pernamkila	Check Dam	74.83689	13.30322
106	Alevuru	Check Dam	74.77386	13.30599
107	Alevuru	Check Dam	74.78879	13.30661
108	Kudhi	Check Dam	74.86208	13.30710
109	Kudhi	Check Dam	74.86494	13.31333
110	Hirebettu	Check Dam	74.82416	13.31380
111	Korangrapadi	Check Dam	74.75843	13.31419
112	Bommarabettu	Check Dam	74.90367	13.31570
113	Kudhi	Check Dam	74.85331	13.31627
114	Kudhi	Check Dam	74.86011	13.32246

115	Hirebettu	Check Dam	74.81903	13.32365
116	Badagabettu-76	Check Dam	74.77624	13.32405
117	Anjaru	Check Dam	74.84050	13.32556
118	Kudhi	Check Dam	74.86251	13.32668
119	Anjaru	Check Dam	74.85125	13.32749
120	Bommarabettu	Check Dam	74.91192	13.32826
121	Bommarabettu	Check Dam	74.90466	13.32931
122	Hirebettu	Check Dam	74.81964	13.32947
123	Bommarabettu	Check Dam	74.88631	13.33046
124	Hirebettu	Check Dam	74.82256	13.33046
125	Bommarabettu	Check Dam	74.86609	13.33074
126	Anjaru	Check Dam	74.83528	13.33277
127	Anjaru	Check Dam	74.82608	13.33304
128	Shiruru	Check Dam	74.94466	13.33522
129	Badagabettu-76	Check Dam	74.76240	13.33595
130	Bommarabettu	Check Dam	74.85171	13.33646
131	Shivalli	Check Dam	74.76737	13.33693
132	Bommarabettu	Check Dam	74.89994	13.33708
133	Shiruru	Check Dam	74.93297	13.33903
134	Badagabettu-80	Check Dam	74.80161	13.33898
135	Bommarabettu	Check Dam	74.86020	13.34079
136	Badagabettu-80	Check Dam	74.81819	13.34076
137	Shivalli	Check Dam	74.76169	13.34180
138	Bommarabettu	Check Dam	74.84481	13.34226
139	Badagabettu-80	Check Dam	74.82700	13.34460
140	Shiruru	Check Dam	74.92574	13.34467
141	Moodanidamburu	Check Dam	74.74512	13.34563
142	Badagabettu-80	Check Dam	74.81846	13.34744
143	Shivalli	Check Dam	74.76691	13.34776
144	Athradi	Check Dam	74.83791	13.34816
145	Shiruru	Check Dam	74.93252	13.34879
146	Anjaru	Check Dam	74.85333	13.34950
147	Badagabettu-80	Check Dam	74.81378	13.34959
148	Shivalli	Check Dam	74.75906	13.35207
149	Anjaru	Check Dam	74.84756	13.35256
150	Shivalli	Check Dam	74.75193	13.35382
151	Shivalli	Check Dam	74.76424	13.35403
152	Putturu	Check Dam	74.74791	13.35533
153	Byrampalli	Check Dam	74.93038	13.35608
154	Athradi	Check Dam	74.82711	13.35744
155	Anjaru	Check Dam	74.85629	13.35764
156	Shivalli	Check Dam	74.77290	13.35793
157	Bommarabettu	Check Dam	74.87883	13.35841
158	Herga	Check Dam	74.79662	13.35938
159	Herga	Check Dam	74.81440	13.35973
160	Bellarapadi	Check Dam	74.88460	13.36060
161	Shivalli	Check Dam	74.75848	13.36108

162	Shivalli	Check Dam	74.76471	13.36233
163	Shivalli	Check Dam	74.75888	13.36396
164	Anjaru	Check Dam	74.86214	13.36552
165	Herga	Check Dam	74.79950	13.36602
166	Kodavuru	Check Dam	74.72774	13.36609
167	Byrampalli	Check Dam	74.92909	13.36640
168	Herga	Check Dam	74.81660	13.36728
169	Herga	Check Dam	74.81358	13.36730
170	Shivalli	Check Dam	74.77884	13.36747
171	Putturu	Check Dam	74.74119	13.36744
172	Herga	Check Dam	74.81244	13.36879
173	Putturu	Check Dam	74.73644	13.36915
174	Thenkanidiyuru	Check Dam	74.71708	13.37001
175	Byrampalli	Check Dam	74.90780	13.37053
176	Shivalli	Check Dam	74.75215	13.37137
177	Shivalli	Check Dam	74.77379	13.37195
178	Shivalli	Check Dam	74.75574	13.37264
179	Perduru	Check Dam	74.89740	13.37534
180	Perduru	Check Dam	74.87514	13.37564
181	Shivalli	Check Dam	74.76493	13.37583
182	Havanje	Check Dam	74.78843	13.37700
183	Bellampalli	Check Dam	74.82737	13.37710
184	Kukkehalli	Check Dam	74.84528	13.37819
185	Herga	Check Dam	74.80418	13.37967
186	Havanje	Check Dam	74.81679	13.38125
187	Havanje	Check Dam	74.79564	13.38206
188	Kukkehalli	Check Dam	74.86577	13.38385
189	Havanje	Check Dam	74.80497	13.38480
190	Uppuru	Check Dam	74.77877	13.38538
191	Havanje	Check Dam	74.80850	13.38558
192	Uppuru	Check Dam	74.76511	13.38570
193	Perduru	Check Dam	74.93972	13.38706
194	Perduru	Check Dam	74.92936	13.38772
195	Bellampalli	Check Dam	74.82306	13.39151
196	Havanje	Check Dam	74.79313	13.39251
197	Havanje	Check Dam	74.79383	13.39617
198	Havanje	Check Dam	74.79790	13.39662
199	Perduru	Check Dam	74.86736	13.39842
200	Shivapura	Check Dam	74.95610	13.39847
201	Havanje	Check Dam	74.80783	13.39943
202	Havanje	Check Dam	74.81301	13.39949
203	Kukkehalli	Check Dam	74.83884	13.40021
204	Bellampalli	Check Dam	74.82712	13.40054
205	Kukkehalli	Check Dam	74.84821	13.40303
206	Perduru	Check Dam	74.88745	13.40364
207	Aruru	Check Dam	74.79263	13.40545
208	Uppuru	Check Dam	74.76622	13.40664

209	Cherkadi	Check Dam	74.83729	13.40741
210	Aruru	Check Dam	74.79581	13.40809
211	Aruru	Check Dam	74.80799	13.40892
212	Perduru	Check Dam	74.90350	13.40962
213	Aruru	Check Dam	74.78491	13.40982
214	Aruru	Check Dam	74.80538	13.41084
215	Cherkadi	Check Dam	74.82525	13.41097
216	Cherkadi	Check Dam	74.81918	13.41258
217	Cherkadi	Check Dam	74.84923	13.41610
218	Perduru	Check Dam	74.93650	13.41844
219	Heruru	Check Dam	74.75644	13.41912
220	Aruru	Check Dam	74.78345	13.42086
221	Aruru	Check Dam	74.79678	13.42308
222	Cherkadi	Check Dam	74.81767	13.42327
223	Perduru	Check Dam	74.92166	13.42340
224	Cherkadi	Check Dam	74.82916	13.42466
225	Halavalli	Check Dam	74.85938	13.42810
226	Hosuru	Check Dam	74.91065	13.42822
227	Chantharu	Check Dam	74.76470	13.43004
228	Cherkadi	Check Dam	74.82313	13.43085
229	Cherkadi	Check Dam	74.79816	13.43289
230	Neelavara	Check Dam	74.78355	13.43351
231	Chantharu	Check Dam	74.75592	13.43399
232	Cherkadi	Check Dam	74.81688	13.43621
233	Cherkadi	Check Dam	74.80760	13.43707
234	Halavalli	Check Dam	74.85709	13.43821
235	Hosuru	Check Dam	74.87511	13.43842
236	Cherkadi	Check Dam	74.81343	13.43875
237	Hosuru	Check Dam	74.88456	13.43947
238	Cherkadi	Check Dam	74.83185	13.44032
239	Cherkadi	Check Dam	74.80390	13.44157
240	Neelavara	Check Dam	74.79433	13.44340
241	Kenjuru	Check Dam	74.89670	13.44351
242	Neelavara	Check Dam	74.77541	13.44499
243	Pejamogru	Check Dam	74.82045	13.44771
244	Neelavara	Check Dam	74.78564	13.44854
245	Neelavara	Check Dam	74.81227	13.44962
246	Kenjuru	Check Dam	74.89067	13.45039
247	Neelavara	Check Dam	74.79678	13.45583
248	Neelavara	Check Dam	74.80233	13.45855
249	Kaduru	Check Dam	74.82747	13.45958
250	Hanehalli	Check Dam	74.77378	13.46073
251	Kudhi	Check Dam	74.87400	13.46300
252	Hanehalli	Check Dam	74.76709	13.46897
253	Kaduru	Check Dam	74.81376	13.46904
254	Hanehalli	Check Dam	74.77299	13.46951
255	Naduru	Check Dam	74.79820	13.47145

256	Nalukuru	Check Dam	74.92131	13.47166
257	Kaduru	Check Dam	74.82496	13.47229
258	Heradi	Check Dam	74.78389	13.47343
259	Naduru	Check Dam	74.78965	13.47657
260	Kudhi	Check Dam	74.86320	13.47675
261	Naduru	Check Dam	74.78681	13.47737
262	Naduru	Check Dam	74.79912	13.47780
263	Nalukuru	Check Dam	74.88158	13.47852
264	Heradi	Check Dam	74.76781	13.48041
265	Naduru	Check Dam	74.80503	13.48095
266	Naduru	Check Dam	74.80205	13.48139
267	Kaduru	Check Dam	74.81885	13.48328
268	Kaduru	Check Dam	74.82623	13.48356
269	Heradi	Check Dam	74.76315	13.48445
270	Heradi	Check Dam	74.75447	13.48660
271	Heggunje	Check Dam	74.82498	13.48818
272	Heggunje	Check Dam	74.80579	13.48829
273	Kaduru	Check Dam	74.81466	13.48860
274	Yedthadi	Check Dam	74.78785	13.48970
275	Shiruru	Check Dam	74.84249	13.49030
276	Yedthadi	Check Dam	74.78044	13.49244
277	Yedthadi	Check Dam	74.76946	13.49248
278	Heggunje	Check Dam	74.82494	13.49275
279	Heggunje	Check Dam	74.82367	13.49457
280	Yedthadi	Check Dam	74.78860	13.49610
281	Heggunje	Check Dam	74.80595	13.49867
282	Kavadi	Check Dam	74.75556	13.49883
283	Heggunje	Check Dam	74.81097	13.50236
284	Yedthadi	Check Dam	74.77772	13.50341
285	Nalukuru	Check Dam	74.88246	13.50480
286	Heggunje	Check Dam	74.81663	13.50487
287	Heggunje	Check Dam	74.79513	13.50501
288	Heggunje	Check Dam	74.83302	13.50536
289	Heggunje	Check Dam	74.80222	13.50600
290	Nancharu	Check Dam	74.86794	13.50615
291	Yedthadi	Check Dam	74.76769	13.50646
292	Yedthadi	Check Dam	74.78756	13.50661
293	Shiruru	Check Dam	74.85376	13.50837
294	Kavadi	Check Dam	74.75603	13.50885
295	Yedthadi	Check Dam	74.79398	13.50889
296	Yedthadi	Check Dam	74.76436	13.51061
297	Billadi	Check Dam	74.79910	13.51602
298	Billadi	Check Dam	74.83023	13.51648
299	Shiriyara	Check Dam	74.78166	13.51645
300	Billadi	Check Dam	74.82301	13.51804
301	Billadi	Check Dam	74.81516	13.51815
302	Shiriyara	Check Dam	74.77102	13.51841

303	Nancharu	Check Dam	74.88796	13.51945
304	Achaladi	Check Dam	74.75741	13.51951
305	Billadi	Check Dam	74.81216	13.52125
306	Billadi	Check Dam	74.80614	13.52149
307	Billadi	Check Dam	74.81570	13.52185
308	Shiriyara	Check Dam	74.76934	13.52200
309	Billadi	Check Dam	74.83466	13.52266
310	Nancharu	Check Dam	74.88071	13.52363
311	Avarse	Check Dam	74.86129	13.52377
312	Billadi	Check Dam	74.79990	13.52380
313	Nancharu	Check Dam	74.88541	13.52430
314	Billadi	Check Dam	74.82132	13.52670
315	Billadi	Check Dam	74.80969	13.52904
316	Hiliyana	Check Dam	74.91087	13.52959
317	Hiliyana	Check Dam	74.90083	13.52983
318	Shiriyara	Check Dam	74.76712	13.53024
319	Billadi	Check Dam	74.81372	13.53149
320	Hiliyana	Check Dam	74.87573	13.53239
321	Avarse	Check Dam	74.87062	13.53481
322	Vandaru	Check Dam	74.84643	13.53506
323	Avarse	Check Dam	74.86051	13.53515
324	Avarse	Check Dam	74.87385	13.53527
325	Billadi	Check Dam	74.81166	13.53544
326	Shiriyara	Check Dam	74.79547	13.53550
327	Hiliyana	Check Dam	74.88729	13.53624
328	Vandaru	Check Dam	74.84405	13.53664
329	Billadi	Check Dam	74.82136	13.53900
330	Hiliyana	Check Dam	74.88409	13.54036
331	Kakkunje	Check Dam	74.83093	13.54035
332	Shiriyara	Check Dam	74.79428	13.54084
333	Vandaru	Check Dam	74.84007	13.54111
334	Avarse	Check Dam	74.86386	13.54420
335	Vandaru	Check Dam	74.84926	13.54745
336	Vandaru	Check Dam	74.84722	13.54831
337	Kakkunje	Check Dam	74.82915	13.54902
338	Hiliyana	Check Dam	74.87983	13.55038
339	Kakkunje	Check Dam	74.83713	13.55279
340	Kakkunje	Check Dam	74.82839	13.55694
341	Kakkunje	Check Dam	74.84318	13.56035
342	Nandhikuru	Percolation Tank	74.79857	13.14122
343	Elluru	Percolation Tank	74.80615	13.16256
344	Elluru	Percolation Tank	74.78956	13.16588
345	Elluru	Percolation Tank	74.80886	13.17030
346	Santhuru	Percolation Tank	74.82462	13.17101
347	Pilaru	Percolation Tank	74.84432	13.17679
348	Elluru	Percolation Tank	74.78911	13.18782
349	Pilaru	Percolation Tank	74.83480	13.19753

350	Kalthuru	Percolation Tank	74.80020	13.22054
351	Shirva	Percolation Tank	74.83716	13.22456
352	Shirva	Percolation Tank	74.81853	13.22850
353	Shirva	Percolation Tank	74.80277	13.25066
354	Shirva	Percolation Tank	74.78845	13.25432
355	Innanje	Percolation Tank	74.77575	13.25687
356	Belle	Percolation Tank	74.80225	13.25975
357	Kattangeri	Percolation Tank	74.83443	13.26414
358	Kattangeri	Percolation Tank	74.83007	13.27326
359	Belle	Percolation Tank	74.81917	13.28277
360	Pernamkila	Percolation Tank	74.84470	13.28730
361	Belle	Percolation Tank	74.80617	13.28793
362	Manipura	Percolation Tank	74.82348	13.29751
363	Kudhi	Percolation Tank	74.86128	13.30319
364	Alevuru	Percolation Tank	74.77478	13.31505
365	Bommarabettu	Percolation Tank	74.89801	13.32137
366	Hirebettu	Percolation Tank	74.83090	13.32666
367	Shiruru	Percolation Tank	74.92470	13.33222
368	Bommarabettu	Percolation Tank	74.85839	13.33260
369	Anjaru	Percolation Tank	74.84716	13.34993
370	Athradi	Percolation Tank	74.82162	13.35461
371	Anjaru	Percolation Tank	74.86064	13.35779
372	Byrampalli	Percolation Tank	74.93684	13.36390
373	Herga	Percolation Tank	74.80366	13.36462
374	Shivalli	Percolation Tank	74.76844	13.36752
375	Shivalli	Percolation Tank	74.75921	13.36937
376	Havanje	Percolation Tank	74.78528	13.38672
377	Kukkehalli	Percolation Tank	74.82895	13.38917
378	Havanje	Percolation Tank	74.81479	13.38922
379	Perduru	Percolation Tank	74.87158	13.39196
380	Havanje	Percolation Tank	74.80437	13.39338
381	Cherkadi	Percolation Tank	74.82239	13.41932
382	Heruru	Percolation Tank	74.74971	13.42431
383	Chantharu	Percolation Tank	74.75816	13.42624
384	Cherkadi	Percolation Tank	74.79517	13.43027
385	Cherkadi	Percolation Tank	74.82772	13.43655
386	Cherkadi	Percolation Tank	74.81428	13.44429
387	Neelavara	Percolation Tank	74.77910	13.44777
388	Cherkadi	Percolation Tank	74.80384	13.44980
389	Nalukuru	Percolation Tank	74.89841	13.46926
390	Naduru	Percolation Tank	74.80843	13.47724
391	Kaduru	Percolation Tank	74.82287	13.47860
392	Naduru	Percolation Tank	74.79683	13.48854
393	Yedthadi	Percolation Tank	74.77466	13.49229
394	Kavadi	Percolation Tank	74.75807	13.49434
395	Nancharu	Percolation Tank	74.89175	13.50409
396	Shiruru	Percolation Tank	74.86044	13.50633

397	Yedthadi	Percolation Tank	74.77723	13.50892
398	Nancharu	Percolation Tank	74.89437	13.51264
399	Yedthadi	Percolation Tank	74.78966	13.51459
400	Shiriyara	Percolation Tank	74.76395	13.51782
401	Billadi	Percolation Tank	74.81857	13.52777
402	Hiliyana	Percolation Tank	74.88340	13.53293
403	Vandaru	Percolation Tank	74.85409	13.53723
404	Kakkunje	Percolation Tank	74.82855	13.53969
405	Kakkunje	Percolation Tank	74.83693	13.55948
406	Nadssalu	Filter bed	74.78006	13.12785
407	Santhuru	Filter bed	74.83509	13.16738
408	Belle	Filter bed	74.79935	13.28791
409	Naduru	Filter bed	74.78701	13.47079

Table 12: Present ground water availability and draft scenario (2022) in Udupi Taluk and expected improvement in Stage of Ground Water Development in future, on implementation of artificial recharge schemes-

Taluk	Cumulative Annual Ground Water Availability	Existing Gross Ground Water Draft for All Uses	Existing Stage of Ground Water Development	Expected Recharge from Proposed Artificial Recharge Structures	Cumulative Ground Water Availability after Artificial Recharge Structure Implementation	Stage of Ground Water Development after Artificial Recharge Structure Implementation	Expected Improvement in Overall Stage of Ground Water Development
	HAM	HAM	%	HAM	HAM	HAM	%
Udupi	**14262.84**	**5650.09**	**39.6**	**5310**	**19572.84**	**28.86**	**10.76**

4.2 Water Use Efficiency by Micro Irrigation Practices

It is observed that wells and bore wells are the source for **7429 ha** of net irrigation in the taluk constituting about 73% of the irrigated area. Adoption of water use efficiency (WUE) techniques will contribute in ground water resource enhancement in the long run by way of saving of water. Efficient irrigation practices like Drip irrigation & sprinkler needs to be adopted by the farmers in the existing 7429 ha of net irrigated area by wells & bore wells. At present (2022), the irrigation draft is **4545.41** ham.

The water efficient methodology may be applied for growing paddy which is grown in 18667 ha and is largely ground water dependent as compared to the other crops which are mainly grown during kharif. Efficient irrigation techniques will contribute in saving ground water by 9333 ham considering 50% of

the paddy area is dependent on ground water irrigation and thus will improve stage of development marginally by **6.17%** from **39.6 to 22.69 %.** However, in long run the practice of Efficient irrigation techniques will add to the ground water resource in large extent. **(Table-13).**

Table 13: Improvement in GW availability (2022) due to saving by adopting water use efficiency

Net annual ground water availability after implementation of AR Structure	Existing gross ground water draft for all uses	Existing stage of ground water development after implementation of AR Structure	Paddy grown area	Paddy area considered for WUE (50%)	Saving due to adopting WUE measures @ 0.57 m in paddy grown area	Cumulative annual ground water availability	Expected improvement in stage of ground water development after the implementation of the project	Expected improvement in overall stage of ground water development
HAM	HAM	%	HA	HA	HAM	HAM	%	%
19572.84	**5650.09**	**28.86**	18667	9333	5320	24,892.84	22.69	16.93

4.3 Ground Water Development Plan

In Udupi taluk, the present stage of ground water extraction (2022) is merely **39.6 %** with net ground water availability of **14262.84** ham and total extraction of **5650.09** ham. The ground water draft for irrigation purpose is @ **4545.41** ham, thus indicating that ground water irrigation needs to be encouraged in the area. Also the less ground water development is most probably linked to the low ground water potential areas and limited aquifer thickness in Aquifer-II. To overcome these, it is imperative to have a robust ground water resource development plan for the area, which can be implemented in scientific manner. The implementation of the plan needs to based on site specific detailed hydrogeological, geophysical and scientific surveys for pinpointing the sites for construction of dugwells and Borewells.

In view of above, the focus of proposed ground water development plan is to up the ante of ground water development from the present 39.6% to 60% in a systematic way by adopting scientific approach. About 3198 dugwells (15-30 m depth; 3 to 5 m diameter @ Rs. 3.00 lakh/dugwell) are recommended to be constructed in feasible areas. Further 29 borewells (40-100 m depth; 150 mm dia @ Rs. 2.00 lakh/borewell) are also recommended to be drilled in feasible areas. Additional irrigation potential which can be created considering crop water requirement of 0.65 m (Ha) will be **4473 ha**. The detailed ground water development strategy to uplift the ground water use in the feasible areas is presented in **Table–14.**

Table–14: Feasibility of additional GW abstraction structures based on GWRA 2022 availability

Balance GWR available to make SOE 60%	DW unit draft	BW unit draft	No. of DW feasible @ 99% with unit draft of 0.9ham	No. of BWs feasible @ 1% with unit draft of 1 ham	Cost of Proposed DW's/year @ unit cost of Rs. 3 lakhs	Cost of Proposed BW's @ unit cost of Rs. 2 lakhs	Additional irrigation potential created by DW's considering crop water requirement of 0.65 m (Ha)	Additional irrigation potential created by BW's considering crop water requirement of 0.65 m (Ha)	Total irrigation potential created by DW's and BW's
2907.61	0.9	1	3198	29	9595	58	4026	447	4473

Note- Hydrogeological and scientific intervention is needed for pinpointing the sites for construction of dugwells and Borewells

4.4 Change in cropping pattern

Change in cropping pattern is necessary since cultivation of water intensive crops like Paddy is prevalent in the Taluk. Though only 18667 hectares is covered under paddy which can effect groundwater availability. At present (2022), the stage of ground water extraction is @ 39.6% and taluk has been categorised as Safe, thus change in cropping pattern has not been suggested.

4.5 Other interventions proposed

- Periodical maintenance of artificial recharge structures should also be incorporated in the Recharge Plan.
- If excess nitrate & fluoride concentration is found in ground water samples, its require remedial measures viz.
    - Dilution of nitrate rich ground water through artificial recharge & water conservation.
    - Roof top rain water harvesting.

5 SUMMARY AND RECOMMENDATIONS

The main ground water issues are Low Ground Water Development, Limited Ground Water Potential / Limited Aquifer Thickness / Sustainability, Deeper Water Levels particularly in Aquifer-II in some parts of areas which are all inter-related or inter dependent and Inferior Ground Water Quality due to nitrate contamination major part of the area. The summary of ground water management plan of Udupi taluk is given in **Table-15.**

Table 15: Summary of Management plan of Udupi taluk

Stage of GW Extraction and Category (2022)	39.6 %, Safe
Annual Extractable GW Resource (Ham)	14262.84
Total Extraction (Ham)	5650.09
Ground Water Draft for Irrigation (Ham)	4545.41
Ground Water Resource Enhancement by Supply side Interventions	
No of Proposed AR structures SSD PT CD	 2 64 341
Expected Additional Recharge to GW due to AR (Ham)	5310.1
Additional Irrigation Potential that can be created (Ha)	6400
Total Estimated Expenditure (Rs. in Cr.)	47.24
Change in Stage of GW Extraction (%)	39.6 to 28.86
Ground Water Resource Savings by Demand side Interventions	
Expected Saving due to adopting WUE measures in Paddy area (Ham)	9333
Change in Stage of GW development (%)	39.6 to 22.69
Ground Water Resource Development Plan	
Balance GWR available to enhance SOE 60% (Ham)	2907.61
No. of wells proposed **DW** – Depth: 15 to 30 m, Dia: 3 to 5 m, Unit Cost –Rs. 3.00 lakh, Av. Annual Gross draft – 0.6 ham **BW** – Depth: 40 to 100 m, Dia: 150 mm, Unit Cost – Rs. 2.00 lakh, Av. Annual Gross draft – 3.9 ham	 3198 29
Additional irrigation potential created considering crop water requirement of 0.65 m (Ha)	4473
Total Increase in Stage of GW Extraction (%)	16.93

As per the resource estimation – 2022, Udupi taluk falls under Safe category with the stage of ground water extraction is 39.6 %. However, there is need to formulate management strategy to tackle the water scarcity related issues in the taluk in the coming days to avoid water crisis in the future. It is suggested to adopt a scientific and multi-pronged ground water management strategy covering supply side interventions, demand side interventions, ground water development interventions and ground water quality protection aspects as mentioned in the management plan suggested above

- **Ground water resource enhancement by supply side interventions**: Quantity of surface water available through non-committed surface run-off is estimated to be 70.802 MCM. This can be used to recharge the aquifer mainly through percolation tanks (64), check dams (341) and sub surface dyke structures (2). The volume of water expected to be conserved/recharged @75% efficiency is 5310 ham through these AR structures. The approximate cost estimate for construction of these AR

structures is Rs. 47.24 Cr. The additional area which can be brought under assured ground water irrigation will be about 0.064 Lakh hectares.

- **Ground water resource enhancement by demand side interventions**: At present about 73 % of irrigation is by wells and bore wells (ground water). The micro irrigation practices like drip and sprinkler irrigation are comparatively less practiced in comparison with traditional surface flooding mode of irrigation. The micro irrigation water efficient methodology needs to be adopted for growing water intensive paddy crop which is grown in 18667 ha and considering 50% area is dependent on ground water irrigation, efficient irrigation techniques will contribute in saving ground water by 9333 ham @ 0.57 m and thus will improve stage of development by 16.93% from 39.6 to 22.69%. However, in long run the practice of efficient irrigation techniques will add to the ground water resource in large extent..
- **Change in cropping pattern**: Farmers are facing inadequacy of groundwater for agriculture during summer. Change in cropping pattern is necessary since cultivation of water intensive crops like Paddy is prevalent in the Taluk. Though generally 18667 hectares is covered under paddy is in Bantwal taluk which can effect groundwater availability. At present (2022), the stage of ground water extraction is @ 39.6% and taluk has been categorised as Safe, thus change in cropping pattern has not been suggested.
- **Ground Water Resource Development Plan:** The present stage of ground water extraction (2022) is merely 39.6 % with net ground water availability of 14262.84 ham and total extraction of 5650.09 ham. The ground water draft for irrigation purpose is @ 4545.41 ham, thus indicating that ground water irrigation needs to be encouraged in the area. To overcome the low ground water development, it is imperative to have a robust ground water resource development plan for the area, which can be implemented in scientific manner. The implementation of the plan needs to based on site specific detailed hydrogeological, geophysical and scientific surveys for pinpointing the sites for construction of dugwells and Borewells.
- In view of above, the focus of proposed ground water development plan is to up the ante of ground water development from the present 39.6 % to 60% in a systematic way by adopting scientific approach. About 3198 dugwells (15-30 m depth; 3 to 5 m diameter @ Rs. 3.00 lakh/dugwell) are recommended to be constructed in feasible areas. Further 29 borewells (40-100 m depth; 150 mm dia @ Rs. 2.00 lakh/borewell) are also recommended to be drilled in feasible areas. Additional irrigation potential which can be created considering crop water requirement of 0.65 m (Ha) will be 4473 ha.
- **Drinking water Supply:** In view of ground water contamination may be with higher concentration EC,Fluoride and Nitrate, drinking water supply from surface water needs to be explored/ ensured.
- **Regulation and control:** Taluk is categorized as **"Safe".** However, the mandatory guidelines like rainwater harvesting and artificial recharge issued by Karnataka Ground Water Authority needs to be strictly implemented in the taluk so that quality of ground water will improve in due course of time.
- **Participatory management:** Awareness programmes and practice of participatory approach needs to be strengthened with the involvement of all the stake holders for sustainable management.

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