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Developing a Sustainable Groundwater Management Plan of Udupi taluk of Udupi District - A Coastal area of Karnataka State

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Abstract
Udupi taluk, part of Udupi district, is classified as "Safe" based on the 2022 dynamic groundwater resource assessment. To improve and manage groundwater resources effectively, a detailed study of aquifer potential is essential. Subsurface aquifer data has been gathered through exploratory drilling and used to create 2D and 3D sections, along with fence diagrams/models using Rockworks software.The Central Ground Water Board's National Aquifer Mapping and Management Program aims to map aquifers, characterize water-bearing formations, and develop management plans for sustainable groundwater use. Although Udupi taluk is categorized as "Safe," maintaining this status requires proper management. With the implementation of Artificial recharge structures, water use efficiency method and irrigation methods like drip and sprinkle can significantly enhance groundwater resources with changes in cropping pattern. The proposed groundwater development plan aims to increase groundwater development from 35% to 60% systematically using a scientific approach.

Keywords: NAQUIM, Groundwater, Safe, Aquifer disposition, Management plan.

1.0 Introduction

National Aquifer Mapping Program was initiated by Central Ground Water Board, Ministry of Jal Shakti, Government of India. Aquifer Mapping is an attempt to combine a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses with a vision to identity and map the aquifers with their characteristics, to quantify the available groundwater resources, to propose plans appropriate to the scale of demand and supply in order to formulate a viable strategy for the sustainable development and management of ground water resources. The Objective of Aquifer Mapping is to define the aquifer geometry, type of aquifers, ground water regime behaviors, hydraulic characteristics and geochemistry of multi-layered aquifer systems on 1:50,000 Scale, Delineation & Disposition of aquifer, aquifer systems in 1:50,000 scale for formulating Aquifer Management Plans.

Udupi taluk is a taluk of Udupi District. Agriculture is the main occupation in the Taluk, since 53% of the total population constitutes the rural population. Most of the agriculture is through Tanks, Borewells, Lift irrigation and Dugwells is the major source of irrigation. In the taluk, the number of Dugwells is 8143 which is used for Irrigation purpose (Source: Statistical Handbook of Udupi District). As the taluk is categorized under ‘Safe’ in Ground water Resource Estimation 2022, the Management plan in taluk should be very strategic and prominent so that the drying condition due to lowering of water level of

aquifer prevented and Groundwater level may be on same level.

2.0 Study Area

Udupi Taluk, Udupi district of Karnataka state covers an area of 942 sq km and located between North latitude 13° 16' to 13° 26' & East longitude 74° 51' to 74° 55' **(Fig.1).** Geology of Udupi taluk comprises of Banded Gneissic Complex which is known as Peninsular Gneissic Complex and Fractured granite which content the secondary porosity and lineament holds groundwater. Geomorphologically, the 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.

The Taluk has Maritime climate. Hot and Humid weather prevails in summer and pleasant during Winter. The area falls under Coastal agro-climatic west flowing river basin and Seetha River is mostly flow through Udupi taluk. Normal annual rainfall in the taluk for the period 2015 to 2022 is 3862 mm (Source-KSNDMC). There are 5 rain gauge stations in the Taluk.

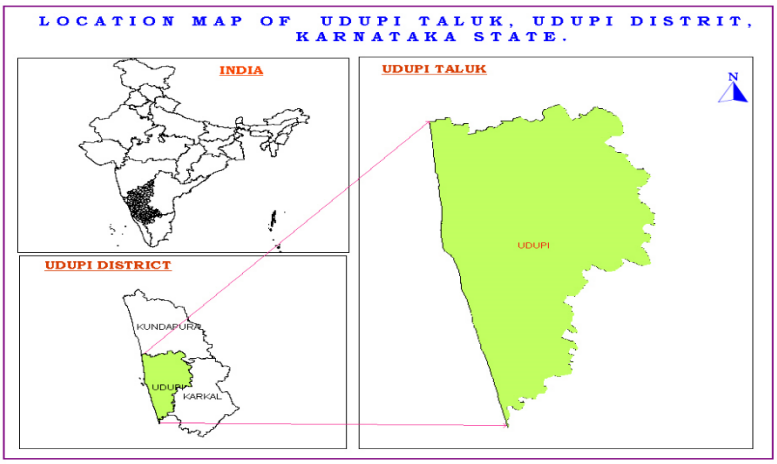


Figure-1: The figure shows the location of study area

3.0 Data and Methodology

National Aquifer Mapping (NAQUIM) is a multidisciplinary approach using advanced tools and techniques including remote sensing, GIS, geophysical techniques, rockworks etc is being followed for preparation of aquifer maps and development of management plans. During Aquifer Mapping, data has to be compiled, utilized and may be generate through data gap analysis. Existing Exploration data, water level data, geophysical data and chemical data compiled and launched into GIS platform to identify and analysis the data gap in the area.**(Fig-2).**

In Udupi taluk, bore wells were drilled to understand the sub-surface aquifer disposition. Based on the data gap analysis, 37 bore-well inventories established. With the help of Borewell data, 2D, 3D aquifer disposition and Aquifer fence diagram has been prepared on Rockworks software. To know the water level trends of study area, Water level monitored in Groundwater monitoring stations of CGWB which is 28 stations, State Government Department data 7 stations and 4 well data of well inventory used to prepare the thematic map of Water level. The thematic map of Water level, weathered zone Map, Hydrogeology Map, and Artificial recharge map are prepared through map info and Arc-GIS software.

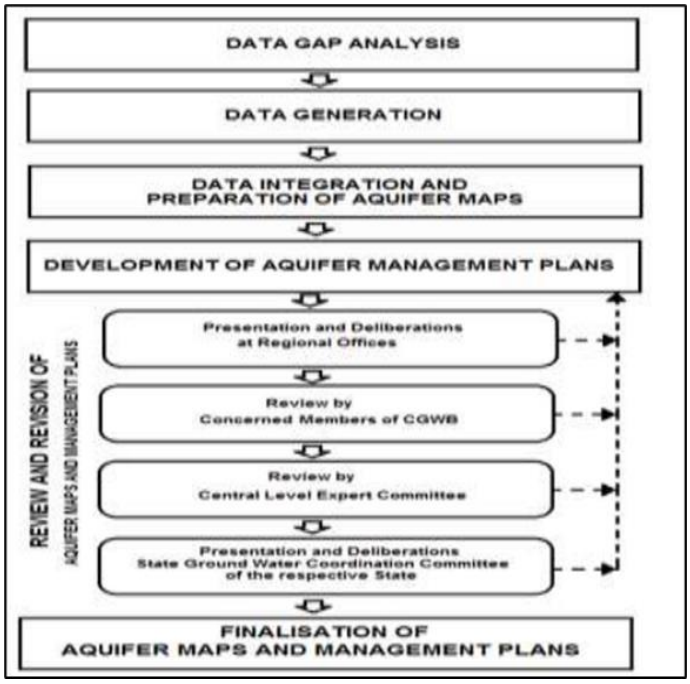


Figure2: Flow diagram for Aquifer Mapping by CGWB

4.0 Results and Discussions

4.1 Ground Water Level:

The Depth to Water level in study area of Udupi taluk showing 3.24 to 15 mbgl during Pre-monsoon and 1.69 to 13.05 mbgl during post-monsoon 2022. In Major part of taluk, the Depth to water level is 5 to 10 mbgl during Pre-monsoon and post-monsoon 2022 Period. **(Fig- 3 and 4)**

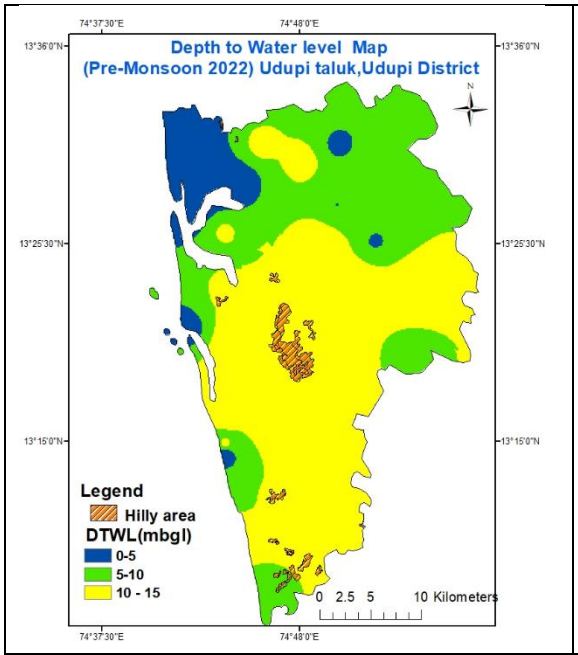


Figure 3: The figure shows the Depth to Water level Map of Pre-monsoon 2022

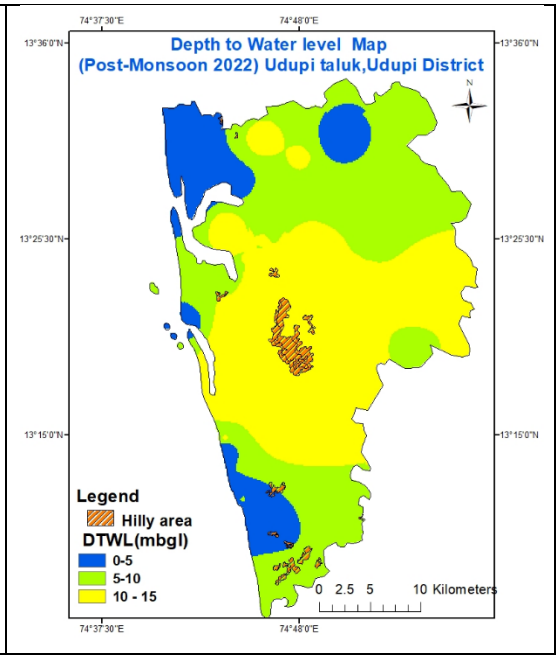


Figure 4: The figure shows the Depth to Water level Map of Post-monsoon 2022

4.2 Hydrogeological Prospect

Geology of the Udupi taluk is Predominantly Banded Gneissic Complex, Alluvium, Hornblende biotite gneiss, Laterite and Pink hornblende Granite (Fig. 5). The water bearing formation is Fractured Granitic Gneiss. In Hard rock terrain, groundwater deposit under fractured Granite which formed due to secondary porosity. In general, the granitic terrain contains good aquifer as compared to gneiss, schist, phyllite, slate, pegmatites, dolerite, volcanic (Igneous) rock. Ground water occurs under water table to semi confined condition depending upon disposition of aquifer which is mainly granite and schist. There are 2 types of aquifers, weathered or phreatic aquifer comprises of weathered granite and fractured aquifer contains joints and Fractures. Weathered zone of study area is upto 30.48 mbgl. Majority of the dug well the 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 mbgl to 15 mbgl. **(Fig-5)**

In Bore well, the Fractured granitic gneiss ranges in depth up to 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. 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. (Source: -KSRSAC) **(Fig-6)**

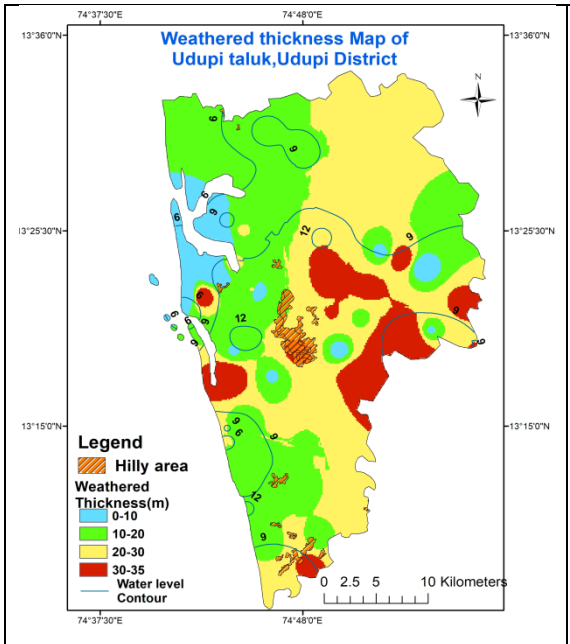


Figure 5: The figure shows the Weathered Map of Study area

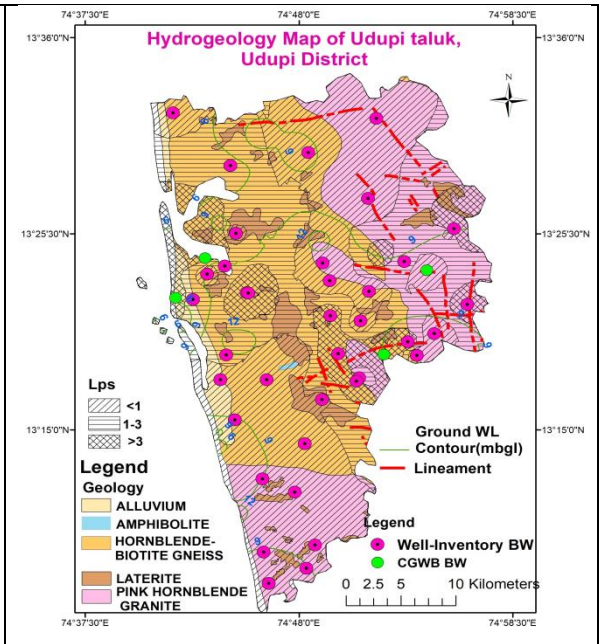


Figure 6: The figure shows the Hydrogeology Map of Study area

4.3 Aquifer Disposition:

The sub-surface aquifer disposition of the study area in 2D and 3D is prepared along with fence diagrams/models through Rock works software **(Fig. 7, 8 &9).**

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-7)**

Hydrogeological cross section A-A' (Fig.-7) represents NW-SE direction and data of 37 exploratory wells has been utilized. 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.-7) represents NE–SW direction and data of 37 exploratory wells has been utilized. 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 BandlessinB.'

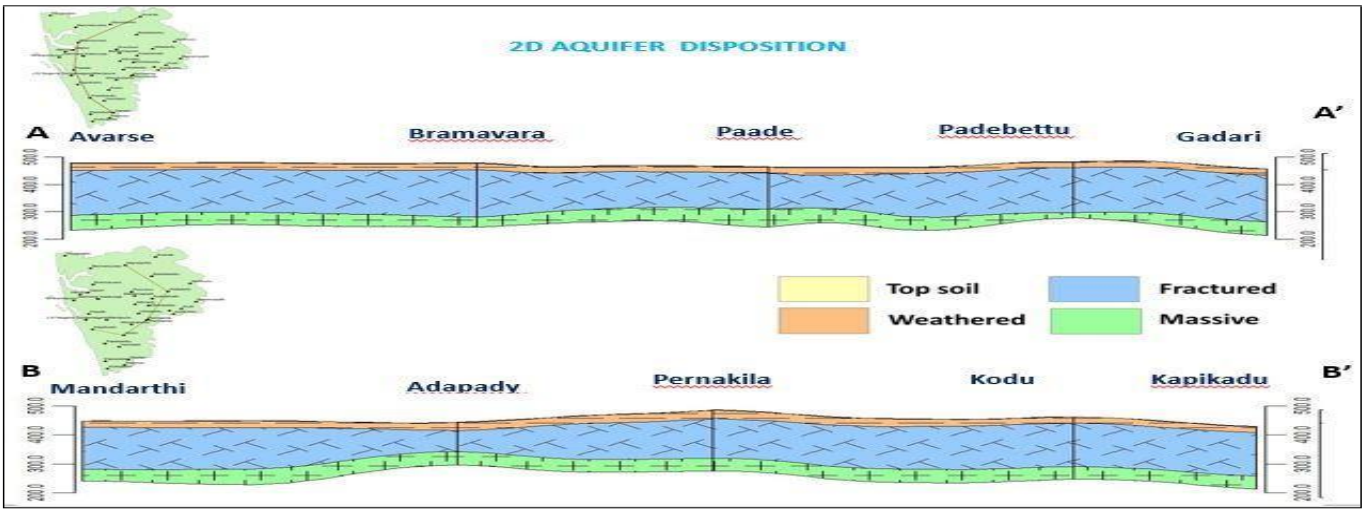


Figure 7: 2D Aquifer Disposition showing the cross-section of study area in variable direction

The fence diagram indicating the disposition of various aquifers is presented in **Fig.-8.** 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.

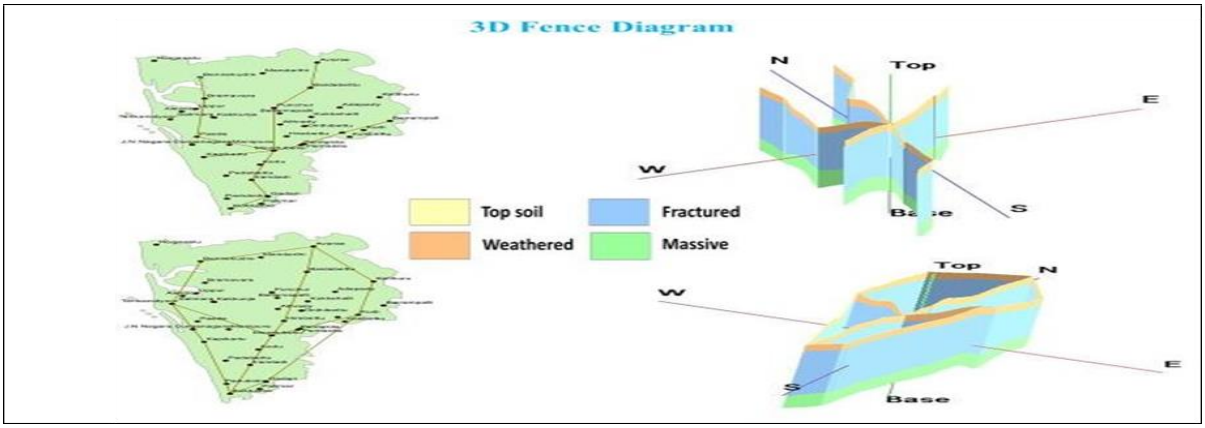
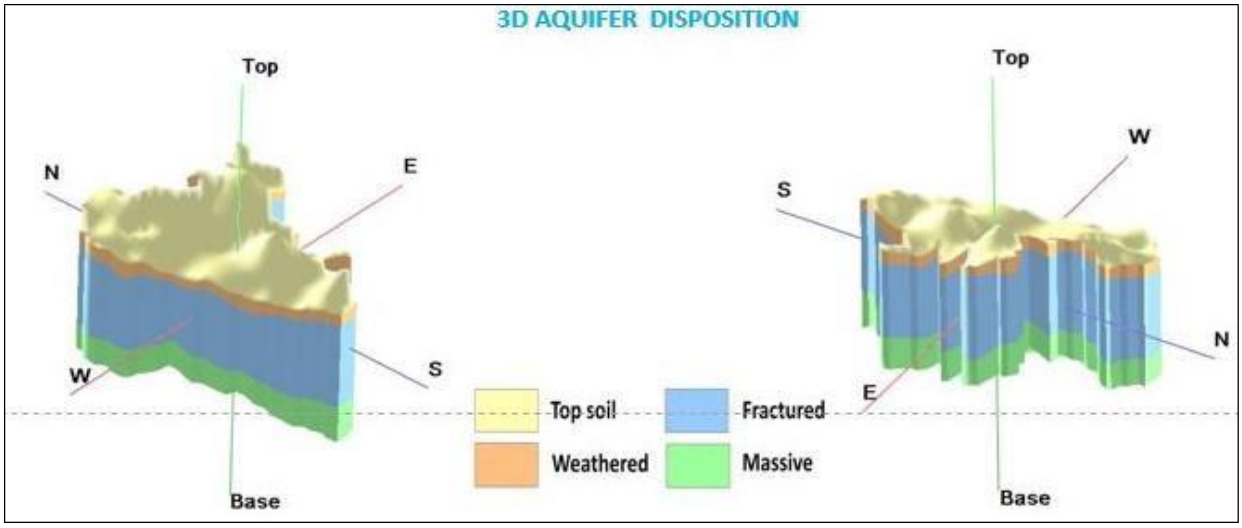


Figure 8: 3D Fence diagrams represent variability of thickness of weathered, fractured and massive formation.



The 3-D representation is presented in **Fig.-9**. 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 mbgl, followed by weathered aquifer observed up to 30 m, which is followed by fractured aquifer which is disposed up to 185 mbgl depth followed by massive formation devoid of ground water.

Figure 9: 3D Aquifer disposition represent the disposition of Aquifer-I and Aquifer-II

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 Udupi 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**.**The depth of Occurrence and thickness of Shallow and Fractured aquifers are presented in **Fig- 10 &11.**

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. 10** 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 mbgl. However, it mainly occurs in the depth range of 6 to 15 mbgl is observed in about 1% of area,15 to 20 mbgl is observed in about 34% of area, 20 to 25 mbgl covering 60% of the area.25-35 m depth occurred in patches in 5% in the 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.

Aquifer – II comprises of Alluvium, amphibolite laterite and fractured Granite Gneiss rock. The spatial distribution of depth of occurrence and aquifer thickness of Aquifer-II is depicted in **Fig. 11** 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 mbgl. However, it mainly occurs in the depth range of 145 to 155 mbgl covering 60% of the area in Northern, western and southern part of the taluk. The depth of occurrence of 95 to 130 mbgl 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.

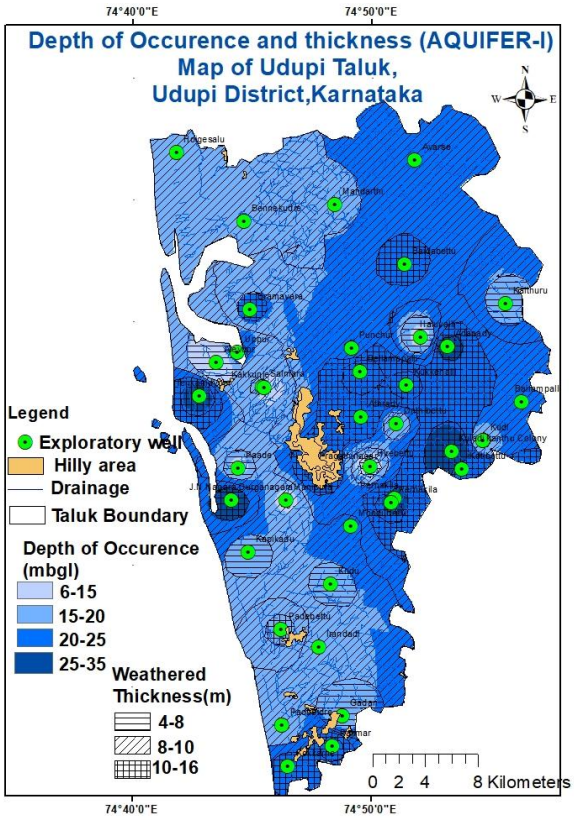


Figure- 10 Depth of Occurrence and thickness Map of Shallow aquifer (Aq-I)

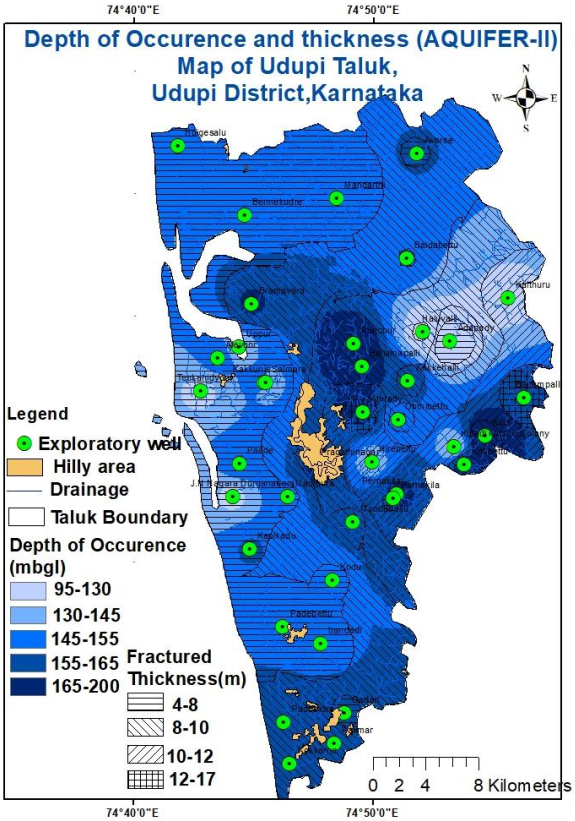


Figure-11DepthofOccurrenceandthickness Map of Deeper Fractured aquifer(Aq-II)

4.4 Groundwater Resource

Ground Water Resource assessment of year 2022 showing that annual extractable groundwater resource is 14262.84 ham and total existing extraction for Irrigation, Domestic and Industrial is 5650.09 ham so based on the GEC calculation, the stage of Groundwater extraction is 39.6% which comes under Safe Category. **(Table-1)**

4.5 Aquifer management plan:

Increase in agricultural activity and excessive ground water withdrawal has resulted in depletion of ground water table and reduction in yield of bore wells. 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.

- **Water Use Efficiency (WUE) Method-** 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% 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 %.(Table-2)**

● **Groundwater 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/dug well) are recommended to be constructed in feasible areas. Further 29 borewells (40-100 m depth; 150 mm diameter @ 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–3).**

● 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 affect groundwater availability.

● Roof top rain water harvesting play an important role for groundwater development.

● **Artificial Recharge Structure-** 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 Artificial Recharge structures. The approximate cost estimate for construction of these Artificial Recharge 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. **(Fig-12 andTable-4)**

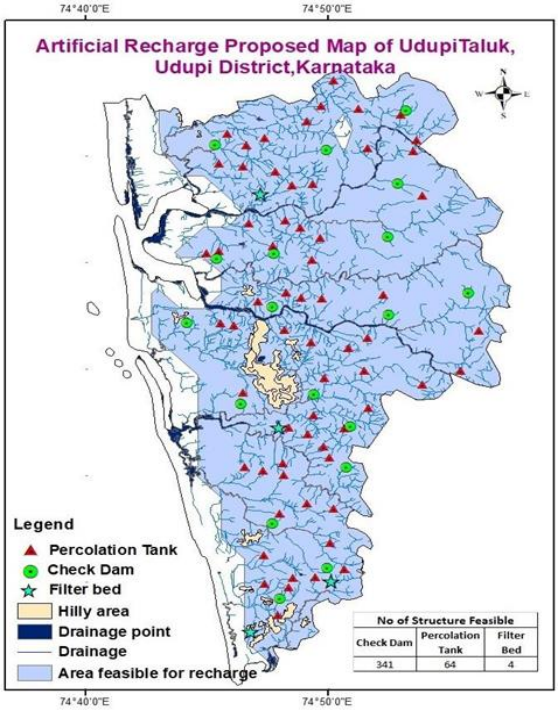


Figure 12: Artificial Recharge Structure Proposed Map

Conclusions

Udupi taluk has been categorized as a "Safe". Management plan with demand and supply sideinterventionin Udupi taluk is mandatory for prevention to depletion of water level as the area is proximity to coastal area. With the demand side intervention,water use efficiency method andirrigation methods like drip and sprinkle should be adopted to add the ground water resource in large extentwith changes in cropping pattern. Awareness Program and Practice of participatory approach need to be strengthened.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 quantity of ground water will improve in due course of time.With the supply side intervention,the implementation of artificial recharge structures like Percolation tank(64 no's),Check Dam(341 no's) and Point recharge structure (13 no's), improved the ground water stage development from 39.6 to 22.69%. Groundwater development from 35% to 60% will create the additional irrigation potential of 4473 ha with the recommendation of 3198 dug wells and 29 borewells in the Udupi taluk.

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Table-1: Ground Water Resource availability and stage of extraction as on 2022 of UdupiTaluk

Taluk	Annual Extract GW resource (ham)	Existing Gross GW extraction for Irrigation (ham)	Existing Gross GW extraction for domestic and industria water supply (ham)	Existing Gross GW extraction for all use (ham)	Allocation for domestic and industrial use for th next 2 years (ham)	Net GW availability for futur Irrigation developmen (ham)	Stage of GW developmen (%)	Category
Udupi	14262.84	4545.41	1104.67	5650.09	1127.7	8579.54	39.6	**Safe**

Table 2: Improvement in GW availability (2022) due to saving by adopting water use efficiency (WUE)

Net annual ground water availability afte implementatior of AR Structur	Existing gross ground water draft fo all uses	Existing stag of groun water development after implementati n of AI Structure	Paddy grown area	Paddy area considere d fo WUE (50%)	Saving du to adoptin WUE measures @ 0.57 n in padd grown are	Cumulative annual ground water availability	Expected improvement i stage of groun water development after th implementation of the project	Expected improveme nt in overa stage o ground water developmer t
HAM	**HAM**	**%**	**HA**	**HA**	**HAM**	**HAM**	**%**	**%**
19572.84	**5650.09**	**28.86**	18667	9333	5320	24,892.84	22.69	16.93

Table–3: Feasibility of additional GW abstraction structures based on GWRA 2022 availability

Balance GWR available to mak SOE 60%	**DW unit draft**	**BW uni draft**	**No. o DW feasible @ 99% with uni draft of 0.9ham**	**No. o BWs feasible @ 1% with uni draft of ham**	**Cost o Proposed DW's/year @ unit cos of Rs. 3 lakhs**	**Cost o Proposed BW's @ unit cost o Rs. 2 lakhs**	**Additional irrigation potential created b DW's considering crop wate requirement of 0.65 m (Ha)**	**Additional irrigation potential created b BW's considering crop wate requirement of 0.65 m (Ha)**	**Total irrigation potential created b DW's an BW's**
2907.6 1	0.9	1	3198	29	9595	58	4026	447	4473

Table-4 Artificial Recharge structures proposed to be made 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**