A CASE STUDY OF THE LITHOLOGICAL STRUCTURE OF WATER BEARING AQUIFERS AND GROUND WATER POTENTIAL IN PUDUCHERRY REGION

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ABSTRACT

The increasing fresh water needs and the growing population rate has resulted in the startling depletion of the water resources in India. The very high population rate has eventually resulted in the drastic changes in per capita consumption among all sectors causing remarkable changes in their absolute and relative magnitude. It has been estimated that the growth of irrigated harvested area will increase at about 3.5% per annum while the growth of the non-irrigated arable area growth will be only 0.5%. The rural population growth has been estimated at 1.0% per annum, but this figure covers both a decline in rural population in industrial areas and a still substantial increase in areas which are predominantly agricultural. Such an increasing stress on the underground aquifer has resulted in appreciable declines to the extent of 3 m in water levels. The paper focuses on a case study on the lithological structure of aquifers and ground water potential in Puducherry region. The objectives of the study are to analyze the lithological structure of the subsurface terrain in the study area and to improve ground water potential of drastically affected cretaceous aquifers in the study area through appropriate recharging techniques.

Keywords **- Aquifers, Artificial Recharging, Ground Water Potential, Lithological Structure**

I. INTRODUCTION

With changing climate, growing levels of water consumption and increasing seasonal variability have led to steady declines in ground water levels posing a serious threat to many of India's inhabitants especially in rural areas [9]. Though previous works have been done based on rain water harvesting and water testing, a thorough study of the lithological structure of the aquifers and the ground water potential of the Puducherry region has not been done yet. Various works pertinent to the focus of the paper have been analyzed. Study on the saturation index of the carbonates in the groundwater using WATEQ4F, in layered coastal aquifers of Puducherry has been performed [1]. Deciphering groundwater flow systems in Oasis Valley, Nevada, using trace element chemistry, multivariate statistics, and geographical information system has been done [2]. A comparative study on the coastal surface and ground water in and around Puduchattiram region, Tamil Nadu has been elucidated [3]. Hydrogeochemical characteristics and evolution of coastal groundwater at Cuddalore Area, Tamil Nadu in India have been analyzed [8]. These works serve as the reference and motivation for the objective of the paper to analyze the lithological structure of the subsurface terrain in the study area and to improve ground water potential of drastically affected cretaceous aquifers in the study area through appropriate recharging techniques.

II. MATERIALS AND METHODS

2.1 Geographical Profile

In this study, lithological structure of the subsurface terrain and ground water potential of drastically affected cretaceous aquifers were analyzed in Puducherry region. The Union Territory of Puducherry consists of four regions situated at different geographical locations isolated from one another, viz. Puducherry region, which is the largest of all the four, lies on the East-coast, consisting of 12 scattered areas lying in between 11^0 42' and 12^0 30' N and between 76^0 36' and 79^0 53'E. Karaikal region is about 150Km South of Puducherry and is surrounded by Nagapattinam District of Tamil Nadu. It is located between $10^0$49' and $11^0$01' N and $79^0$43' and $79^0$52'E. Yanam region is located between $16^0$42' and $16^0$46'N and $82^0$11' and $82^0$19'E at about 840Km North East of Puducherry between $11^0$42' and $11^0$43' N and $73^0$31' and $75^0$33' E at 653 Km away on the West – coast near Tellicherry in Kerala with total area of 492 Sq.Km. (Puducherry -293 Sq.Km, Karaikal -160 Sq.Km, Yanam -17 Sq. Km and Mahe - 9 Sq. Km) Puducherry Region lies discontinuously at the tail end of two river basins Viz. River Gingee and Ponniyar.

2.2 Geology and Structure

Except for a meagre part of the North-Eastern corner of Puducherry region, the entire area is covered by sedimentary formations ranging in age from Cretaceous to recent. Outcrops of these formations are sparse and to supplement the surface geology and to establish the stratigraphy of the area, the Oil and Natural Gas Commission (ONGC) had carried out detailed geological geophysical surveys and drilled 9 shallow boreholes in 1971. The general stratigraphic succession has been presented in table 1 (Source: State Ground Water Authority, Puducherry).

Cretaceous Sediments

The oldest sedimentary formation is of Cretaceous period and is exposed in the North-Western part of the region and North of Gingee River. The trend of these formations is NE-SW. Four stratigraphic units have been identified in 1971 namely Ramanathapuram, Vanur, Ottai and Turuvai formation.

Ramanathapuram Formation

The Ramanathapuram formation representing the Lower Cretaceous age is not exposed anywhere. They were encountered only in boreholes drilled to the North of Gingee River and also between Pennaiyar and Gingee River on the Western part of the region. At Ramanathapuram, they are unconformably overlain by younger Cuddalore formation, whereas in the rest of the area drilled, they are overlain by Vanur Sandstones.

Archaens

The Archaens are represented by the rocks of Eastern Ghats complex compressing charnockites and gneisses. Coarse grained and charnockites is noticed in the low mounts along the bed Gingee River West of Thiruvakarai. The biotite – hornblende gneiss is exposed North West of Puducherry region associated with charnockites. The Eastern Ghats complex forms the basement for Cretaceous – Tertiary sediments in the region. The yield of wells drilled in this formation in general is meagre.

Vanur Sandstone

The Vanur sandstone represents the oldest unit of Upper Cretaceous formation. These formations comprise coarse-grained, friable, greyish white, pebbly sandstones, feldspathic at places with veins of aragonite and with thin intercalations of dark grey to greenish grey shales. Garnet is the major heavy mineral. These are found exposed in the open well-sections at Vanur, Katterikuppam and Thailapuram. These sandstones are also

encountered in the boreholes drilled to the North of Gingee River in the Eastern part of the study area between Pennaiyar and Gingee River. The thickness of this formation is 152 m at Vanur, whereas it is only 52m at Katterikuppam.

TABLE I. **GENERAL STRATIGRAPHIC SUCCESSION OF THE STUDY AREA**

Era	Period	Formations	Lithology
Quaternary	Recent	Alluvium	Sands, clays, silts, Kankar and gravels
Tertiary	Mio-Pliocone	Cuddalore Formation	Pebbly and gravelly and coarse grained sandstones with minor clays and siltstones with thin seams of lignite.
---- Unconformity ----			
	Paleocene	Manaveli Formation	Yellow and yellowish brown, grey calcareous siltstone and claystone and shale with thin bands of limestone.
		Kadapperi kuppam Formation	Yellowish white to dirty white sandy, hard fossiliferous limestone calcareous sandstone and clays.
---- Unconformity ----			
		Thuruvai limestone	Highly fossiliferous limestone, conglomerate at places, calcareous sandstone and clays.
	Upper cretaceous	Ottai clay stone	Greyish to grayish green clay stones, Silts with thin bands of sandy limestone and fine grained calcareous stand stone.
		Vanur sandstone	Quartzite sandstones, hard, coarse grained, occasionally feldspathick or calcareous with minor case.
Mesozoic	Lower cretaceous	Ramanathapuram formation	Black arbonaceous silty clays and fine to medium grained sands with bands of lignite and medium to coarse grained andstones.
---- Unconformity ----			
Archaean		Eastern Ghat complex	Charnockite and biotite-hornblende gneiss.

They comprise alternate layers of grey sandstone and carbonaceous-clay stone with thin seams of lignite. The thickness of this formation ranges between 55m and 250 m.

Ottai Claystone

The Ottai formation consists of black to greenish grey clay stone with few bands of limestone and calcareous and micaceous silts and siltstones. These are exposed in comparatively larger area of the Cretaceous sediments covering part of Valudhavur, Ottai and Pulichappallam villages, North of Gingee River. These formations are encountered in the boreholes drilled to the North of Gingee River and in deeper boreholes drilled to the South of Gingee River in the Western half of the region. The outcrops of this formation are commonly yellowish grey in colour. The thickness of this formation is about 139 m at Karasur (just close to the outcrop), over 231m at Lake Estate and about 88m at Kalapet. This formation thins towards North East at Auroville and Kalapet.

Turuvai Limestone

The uppermost of the Upper Cretaceous formation known as Turuvai limestone exposed as a narrow strip in NE-SW direction, extending from Mettuveli in the South to Apprempattu of Tamil Nadu in the North. The Turuvai formation consists of fossiliferous, cement grey limestone with few bands of sandstones. The fossils include corals, mollusks and brachiopods. These are highly conglomeratic with pebbles of quartz at places as seen in the dug well section at Royapudupakkam. Because of the limited thickness and lateral variations, these could not be traced in some of the boreholes drilled by Central Groundwater Board. They are encountered in the boreholes

drilled by Central Groundwater Board at Karasur and at Alankuppam. It is also encountered in the ONGC borehole drilled to the North of Gingee River at Koluvari.

Paleocene (Tertiary) Sediments

The Paleocene formation of Lower Tertiary is represented by the Kadapperikuppam and Manaveli formation in the region. The trend of this formation is similar to the Cretaceous formation.

Kadapperikuppam Formation

The Kadapperikuppam formation is exposed near Pillaiyarkuppam, Sedarapet, Kadapperikuppam and Alankuppam. These formations are predominantly calcareous sandstones, yellowish grey to dirty white in colour with thin lenses of clay and shale and bands of shell limestone. They are encountered in the boreholes drilled in the Eastern half of the area lying North of Gingee River and in the deeper boreholes drilled on the Southern side of Gingee River except in the NorthWestern corner of Mannadipet commune. The thickness of these formations varies widely which may be due to the unevenness of the Cretaceous basement.

Manaveli Formation

The Manaveli formation belongs to Upper Paleocene age. These formations comprise yellowish brown calcareous sandy clay and shale with thin shell and limestone bands. The upper contact with Cuddalore sandstone is unconformable and is marked by laterite. These formations occur in a small stretch covering the villages Manaveli, Thiruchitrambalam, Kottakkarai and East of Alankuppam. These are encountered in the boreholes drilled in the areas to the North and South of Gingee River towards East.

Mio-Pliocene Sediments

The Mio-Pliocene formation is represented by Cuddalore formation.

Cuddalore Formation

The Cuddalore formation are composed of thick succession of pebbly and gravelly, coarse-grained sandstones with minor clays, rarely with thin seams of lignite. Silicified wood has been noticed at places in the outcrops and well sections. They occur as two widely separated outcrops as ferruginous laterite high ground, one on the North Western margin known as Tiruvakkarai ridge and the other in North Eastern portion along the coast. All other older formations are cropped out in between these two patches. In the North Western margin, the Cuddalore formation overlies the Ramanathapuram formation by completely concealing them and overlapping the Vanur sandstones. In the North Eastern portion they overlie the Manaveli formation. The thickness of these formations varies from 30m to 130m at outcrop area and maximum thickness of 450m is observed at Manapet along the coast in the South Eastern side.

Recent (Quaternary) Formations

The Recent (Quaternary) formations in the region are represented by laterites and alluvium. Laterite occurs as thin cap over the Cuddalore formations. Thick alluvial deposits are formed along the course of Pennaiyar and Gingee rivers covering three-fourth of Puducherry region. It occurs in the inter-stream area and also North of Gingee River extending from Puducherry town to the West. The alluvium in the area is composed of sands, clays, silts, gravels and kankar. The thickness of alluvium varies from 10m to 55 m with a maximum of 55m at Sathamangalam.

Facies Changes

The Cretaceous and the Paleocene formations exhibit wide variations both vertically and laterally. The Ramanathapuram and Vanur formations which are coarser and clastic in the North West, closer to the provenance becoming finer clastics and limestone bands in the down dip direction. The Kadapperikuppam formation showed

wide variation along the strike, even in the outcrop area. The various formations when followed down the dip direction are often difficult to identify based purely on litho logical considerations.

2.3 Fence Diagram

To obtain a comprehensive picture of the disposition of the various geological formations in the area, a panel diagram is prepared based on the data of selective boreholes drilled in the area as shown in fig 1 (Source : State Ground Water Authority and Agriculture Department, Puducherry). A study of the panel diagram revealed the following salient points:

i. The thickness of sedimentary formations in the Northern part of the area (North of Gingee River) is comparatively less and it increases towards South and South East. The thickness of sediments which is around 190 m in the NW increases to 500 m in the South-East.
ii. The alluvial formations exhibit maximum thickness (51m) at the center.
iii. The Cuddalore sandstone formation attains a maximum thickness of 456m towards South-East and pinch off to about 30m in the North-East.
iv. The dip of the Cuddalore sandstone formation seems to be more (around 10^0) than the older Paleocene and Cretaceous formations which were reported to be around 2^0 to 5^0.

III. STATUS OF GROUND WATER

The main source of water supply for all purposes such as agriculture, drinking, domestic is groundwater, which is extracted from 3 major aquifers viz., Alluvium, Tertiary and Cretaceous and irrigation is supplemented by 84 Nos. of System and non-system tanks.

Owing to the population growth, intensive agriculture and rapid phase of industrial development the demand for water has increased considerably which resulted in over exploitation of ground water, which ultimately lead to drastic depletion in groundwater levels and deterioration of water quality due to upward movement of chemical constituents present in deep seated aquifer.

The worst affected area is the Northern part of Puducherry region where the potential aquifer (Vanur sandstone) is cretaceous aquifer. The presence of very thick and very hard arenaceous limestone formation over the creataceous aquifer prevents the recharge in that area and affects the replenishment of groundwater potential in that area. The Piezometric pressure head of the cretaceous aquifer was in the range of 15 to 20 m during 1980 to 1990 and the present pressure head at present is around 30 to 65 m.

Due to increased demand for potable water due to rapid growth in population and the subsequent demand on food grains, there is tremendous pressure on water and land resources which are showing sign of severe stress at the dawn of the new century.

3.1 Ground Water Availability

Groundwater is the main source for irrigation, drinking and industrial needs. In this region, there are three major aquifer systems namely alluvium, Cuddalore sandstone and Vanur-Ramanathapuram Sandstone. Besides these aquifers, Ottai granular zones and Kadarperikuppam limestone also contributes groundwater to some extent.

As per the ground water recharge estimation, the utilizable groundwater resource at 85% of the recharge potential is assessed at 151MCM. The present total ground water draft to meet the needs of all the sectors is in the order of 169MCM. It is evident that the maximum limit of utilization of groundwater exceeds the resources availability in Puducherry region resulting in over exploitation of groundwater.

Puducherry is endowed with substantial ground water resources. The utilizable ground water resource (at 85 per cent of the gross recharge potential) is assessed at 151 MCM. Since alluvial aquifers cover about 90 per cent of

the Puducherry region, water level in the wells is fairly shallow ranging between 12 to 14 meters below ground level. In the tank command area alone there are 70-80 shallow wells and about 1000 tube wells. Overall, there are some 8200 tube wells in the Puducherry region which extract water for agriculture, industry and domestic purposes. In the study area which includes villages namely Thethampakkam, Suthukeny, Katterikuppam, Lingareddipalayam, Karasur, Thuthipet, Sedarapet, Thondamanatham to a total extend of 32.36 Sq/km. depend upon ground water sources being taped mainly from Vanur Sandstone Aquifers for agriculture and domestic purposes. The thickness of aquifers changes from 26mts – 63 m at study area.

3.2 Ground Water Depletion

The state groundwater unit of Agriculture Department is monitoring the groundwater fluctuation through various stations located in and around Puducherry.

Groundwater fulfils the needs of irrigation, drinking and industrial needs in Puducherry region. Canals and tube-wells are the main sources of irrigation in the study area. The consumption of groundwater for irrigation amounts to around 80% of the total water consumption of all sectors. The surface water bodies like tanks and ponds, which were supplementing irrigation in the sixties, have become defunct.

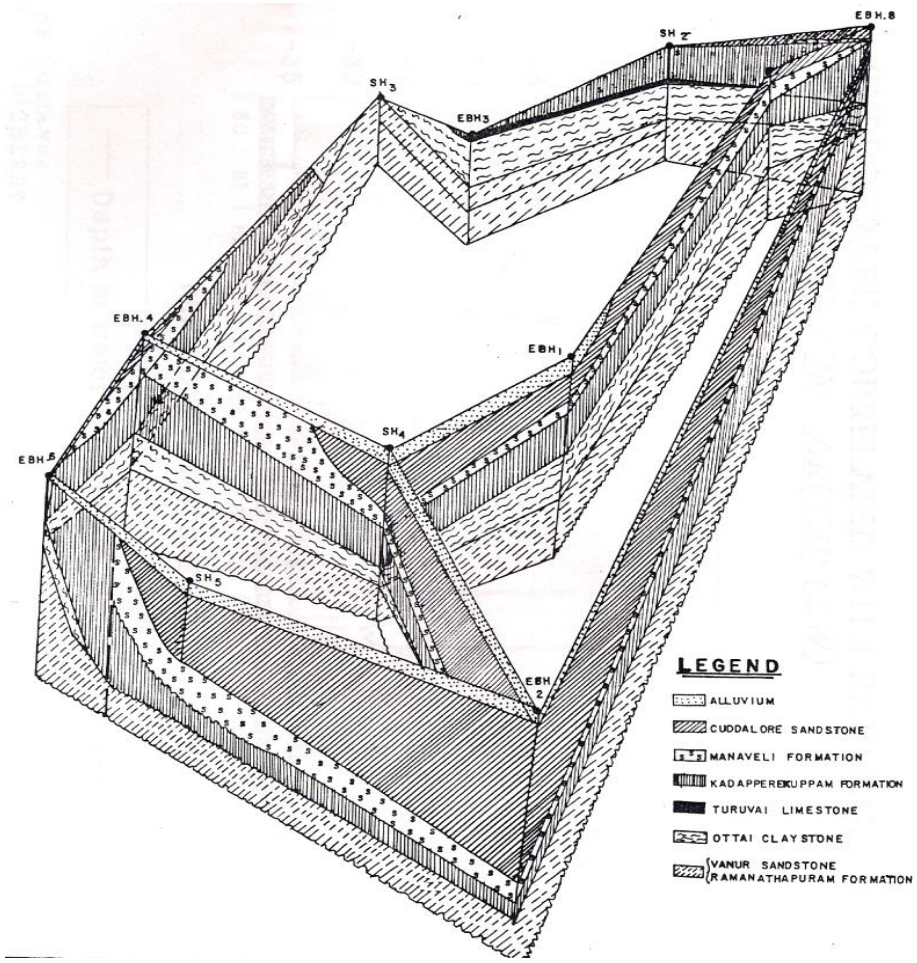

Figure 1. Fence Diagram showing disposition of geological formations in Puducherry region

Presently the water requirements for all purposes are being fully met out by groundwater resources and the extraction of groundwater has crossed the average annual replenishment to the aquifers. Owing to this, there is a

steep decline of water level in the aquifers to depth ranging from 15m to 35m and also salt water intrusion occurred in coastal Alluvial aquifers.

The Piezometric head is now far below the sea level. On comparing the water level data over a period of 17 years i.e., from 1981 to 1998, it was noticed, that depending on the area, there was a drop in water level from 6mts to 26mts over the years 4 maximum drop of 26mts was observed around Katterikuppam area mainly because of increase in sugarcane command are from 1328 ha during 1965-66 to 3300 ha in 1994-95 consequent to the setting up of the Puducherry co-op sugar mills at Lingareddipalayam.

In general, it is found that the water levels are declining gradually due to over exploitation of ground water for agriculture and other purposes, vagaries of monsoons and non receipt of water in surface water reservoirs.

The excess rainfall during 1996 and 1997 has contributed for the recharge potential to ground water systems but not to the expected levels because of the reduction in the storage capacity of all the surface water reservoirs.

IV. FACTORS AFFECTING THE WATER RESOURCES

- Climate and environmental changes

Due to climatic changes globally timing of onset of monsoons is likely to change. In such cases, frequent floods or drought situation are likely. This may seriously affect the storage position of the reservoirs and in turn natural recharge of ground water resources. Unless otherwise the ground resources are managed properly, the effective utilization of conjunctive use could not be achieved. In Karaikal and Puducherry region it is noticed that the backwater have moved upto 2-4kms inland causing Stalinization in the top alluvial aquifers.

- Over Exploitation of Groundwater

The present abstraction of groundwater has crossed more than the average annual replenishment to the aquifers and hence salt water intrusion has occurred all along the coast to a distance of 1-3kms inland causing irreversible damage to the alluvial and tertiary aquifers.

V. CRETACEOUS AQUIFERS

- Ramanathapuram and Vanur Aquifers

Among the various water bearing formations of Cretaceous age, the Ramanathapuram and Vanur formations form potential aquifers. They occur in the North-Western part of Puducherry region, and are encountered in boreholes drilled in the major part of the region. The aquifers of this formation include sands and calcareous sandstones.

They are coarse grained in the Western part and graded into finer facies towards East and NorthEast. The thickness of these aquifers ranges between 38m and 92m. Groundwater occurs under confined conditions and the piezometric head at present is about 20m to 60m below ground level. The depth of the tube wells tapping these aquifers ranges between 65m in the NW and 300m in the NE of Puducherry region.

The yield of the tube wells tapping these aquifers ranges between 120 lpm and 700 lpm. The investigation carried out reveals that the Transmissivity value of these aquifers ranges between 92 m^2/day and 1925 m^2/day. The Storage Coefficient value ranges between $2.93x10^{-5}$ and $1.36x10^{-4}$.

- Ottai Aquifers

The Upper Cretaceous Ottai formations are constituted mainly by clay stone, the water-bearing property of Ottai aquifers is chiefly dependent on the few bands of fine grained sandstone and limestone occurring locally at deeper depths and as a result, it yields meager to moderate quantity of water. Two tube wells constructed at Lake Estate farm, by Central Groundwater Board (1993) tapping mainly these aquifers show a field permeability ranging

from 2.5 m/d. to 11 m/d. The thickness of this aquifer varies from 42m to 56m and yield of the wells ranges between 120 lpm and 600 lpm with draw down varying from 6.6m to 25m.

- Teritiary Aquifers

The Manaveli formation of Paleocene is mainly an aquitard and the localized granular zones do not provide any appreciable yield. Another unit of this group namely, the Kadapperikuppam formation contains some productive aquifers. The thickness of this aquifer show wide lateral and vertical variations. Amongst Tertiary aquifers, the Cuddalore sandstones of Mio-Pliocene age constitute the most potential aquifers.

- Kadapperikkuppam Aquifers

The aquifers of this group are constituted by fine-grained sandstones and give moderate to good yield as seen around Sedarapet, Pillaiyarkuppam and further NorthEast. The thickness of aquifer ranges between 52m and 90m in the areas to South of Gingee river, whereas in the areas to the North of Gingee river, it is between 13m and 37m. Groundwater occurs under un-confined condition. The investigation carried out reveals a field permeability of 3m/day in the areas to the South of Gingee river, whereas towards North of Gingee River it is around 0.8 m/day.

- Cuddalore Sandstone Aquifers

The Cuddalore Sandstones (Upper Tertiary) comprising sandstones, and gravels, occupy an extensive area in the region. This aquifer attains maximum thickness in Bahour, Ariyankuppam, Puducherry, Eastern Nettapakkam commune, in major part of Ozhukarai and in Villianur communes, East of Villianur and South of Gingee river. The thickness of this aquifer in Ozhukarai commune to the North of Gingee River ranges between 20m and 66m and the maximum thickness of 245m is encountered in Bahour commune in the Southern part of the region.

Groundwater occurs in this aquifer mainly under confined condition and is developed by means of tube wells ranging in depth between 27m and 200m below ground level. The yield of the tube wells tapping this aquifer ranges between 200 lpm and 3000 lpm with drawdown varying from 5m to 10m. The piezometric level in this aquifer ranges between 10m and 25m below ground level. The investigation carried out reveals that the average Tranmissivity values of these aquifers are around 2,000m^2/day. The Storage Co-efficient value ranges between $9.583x10^{-5}$ and $8.9x10^{-4}$.

- Alluvial Aquifer

Sands and gravels constitute the alluvial aquifer. Alluvial deposits occupy nearly three fourth of the study area. These aquifers form the most potential shallow aquifer system of the study area, with thickness ranging between 5m and 34m. Thick alluvial aquifers occur in the area bordered by Thirukanji, Odiyampet, Thavalakuppam, Villianur, Mangalam and Sathamangalam. Groundwater occurs in this aquifer under un-confined to semi-confined condition.

The depth of the tube wells tapping this aquifer ranges between 25m and 50m below ground level. The average annual fluctuation is around 7.50m. The studies (CGWB, 1993) indicate that the Transmissivity values of the aquifers in the West are 275.4m^2/d at Madukarai and 770m^2/d at Thirukanji in the East.

VI. RESULTS AND DISCUSSION

From the analysis of lithological data, the thickness ranges from 3 m to 44 m for Cuddalore sand stone aquifer. For Thuruvai lime stone aquifer, thickness ranges between 14 and 157 m. The thickness of Ottai clay stone aquifer ranges between 3m and 143m. The thickness of Vanur sand stone aquifer ranges between 14 and 116.

6.1 Ground Water Quality

The ground water of alluvial aquifer is almost neutral to alkaline in nature with pH values ranging from 7 to 8.5. The water is generally bicarbonate chloride type, the bicarbonate is predominating over chloride. Carbonate is generally absent or occurs in traces. Chloride content is generally below the permissible limit except in few places along the coast. The electrical conductivity ranges from 1500 to 2000 micro mhos / cm at 250C.

The quality of ground water being tapped from Tertiary aquifer is alkaline with pH ranging from 7.4 to 8.5. Carbonate is almost nil and the ground water is generally calcium Magnesium bicarbonate type.

Ground water from all the aquifer system is in general, suitable for both domestic and irrigational purpose. However, water with high salinity and medium sodium hazard are reported from both alluvial and Tertiary aquifers in the coastal areas of Puducherry region. Very high salinity and high sodium are reported from select wells along the coast due to sea water intrusion. This is listed in table 2 (Source: Public Health Laboratory, PWD, and UTOPHO, Puducherry).

The quality of ground water in the Cretaceous aquifer is slightly alkaline with pH ranging from 7.7 to 8.5. The concentration of chloride is generally within 150ppm.

The electrical conductivity values are less than 1500 micro mhos/cm at 250C. on the other hand PH value in bore wells at study area is ranging from 7 to 7.5 chloride concentration values ranging from 27 to 86 and EC is less than 980. In general the quality of water is fit for domestic and irrigation purposes.

However, the flow of groundwater, which was from the Western parts of the region towards the sea before 1985, reversed its direction after 1985 and the groundwater flow is now from East to West.

By taking into consideration the quality of water in the villages like Katteri, Kuppam, Thethampakkam, etc, located in the study area, it is proposed to enhance the recharge potential of these villages, so that water quality can be maintained, when the groundwater flow direction gets normalized and flows towards Eastern direction.

TABLE II. WATER QUALITY IN THE STUDY AREA

Parameter	**Kattrikuppam Main canal**	**Kattrikuppam lake**	**Kuppam Thangal Lake**	**Lingarredipalayam**	**Kuppam bore well**	**Katteri Bore well**
Organoleptic Properties	Hazy water	Hazy water	Hazy water	Clear water	Clear water	Clear water
Conductivity (micrmhos/cm)	660	470	1280	550	980	780
pH	6.9	8.6	8.8	7.5	7.0	7.1
DO (mg/L)	420	300	810	350	615	490
Alkalinity (mg/L)	208	160	220	244	333	328
Hardness (mg/L)	184	132	264	202	395	359
Ca (mg/L)	23	22	42	36	66	59
Mg(mg/L)	30	19	40	28	58	43
Fe (mg/L)	0.15	0.2	0.35	0.15	0.25	0.25
Cl^-(mg/L)	96	72	284	37	86	27
So_4(mg/L)	25	8	102	30	26	15
F^-(mg/L)	0.10	0.10	0.10	0.10	0.15	0.15

VII. SUMMARY AND CONCLUSION

The ever increasing groundwater usage for domestic and agriculture purposes has lead to a grave situation in the study area. The following points are to be considered to augment water potential for affected aquifer. The ground

water depletion should be controlled at the drastically affected area. The design of tube wells in the affected area should be based on the designed discharge economically viable command area.

The water management process such as rehabilitation tanks, canals, drip irrigation etc., and changing of cropping pattern so as to avoid heavy water consuming crops like sugar cane, paddy etc., have to be adopted based on availability of water and its efficient usage. The increasing Piezometric head due to increased draft of groundwater will affect the quality of water and therefore close monitoring and water quality at the study area is essential. Suitable measures have to be taken up for increasing the quantum of storage in the existing tanks like desilting, rising of bunds etc., to facilitate recharge of aquifers to a considerable extent. Moreover suitable techniques of artificial recharging of aquifers have to be adopted at suitable locations.

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