International Journal of Engineering & Technology, 7 (2.25) (2018) 32-36

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Investigation of Ground Water Depletion Pattern across Chennai City

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Abstract

An attempt has been made to investigate both seasonal and long term ground water depletion pattern across the aquifers lying below geographical boundary of Chennai city. The Depth below Ground Level (DBGL) is used as an analyzing parameter for this investigation. This analysis is based on the data that has been made available to the public by Central Ground Water Board (CGWB) and Water Resources Department, Chennai, Tamil Nadu. Both graphical analysis and statistical based regression analysis has been carried out and the result has been presented in graphical and tabular form. Seasonal DBGL variation has been analyzed for the year 2016 after the popular Chennai 2015 December Flood event. It has been observed that the range of ground water level depletion is from 0.1 m per month at Broadway and up to 0.833 m per month at T.S.Campus locations during post monsoon season from January to May. Long term DBGL variation has been analyzed for duration of 22 years from 1996 to 2017. Statistical package for social sciences (SPSS) has been used to perform both linear and other regression analysis. Sustained decrease in ground water level has been observed at locations like Perambur Kodambakkam and Vallalar Nagar during the last two decades.

Keywords: *Conjunctive water use;Depth below ground level (DBGL); Ground water depletion; Regression coefficient*

1. Introduction

It has been estimated by UNESCO, 1975 that the total quantity of water in the world is to be about 1386 million cubic kilometer (M km^3). About 96.5% of this water is contained in the ocean as saline water. Only 35 M km^3 of fresh water is available because about 1% of water available in the land is also saline. Out of this 24.4 M $km^3$of water is contained in frozen state as ice in the polar region. The remaining 10.6 M km^3 is both liquid and fresh.
The hydrological phenomena changes the contribution of ground water potential with respect to that of other sources of water. With respect to Surface water the ground is a kind of sustained water that is available for a long period of time after the given rain fall. The reliability of the ground water is much higher than that of surface water.
Hence for the efficient management of the ground water potential the monitoring of the ground water depletion pattern and modeling of the ground water flow pattern becomes the area of focus.

2. Literature Review

The conjunctive use of surface and ground water strategy is always used to optimize the water resources management practices. Agricultural Statistics at Glance 2014[1] reported that the increase in the use of ground water for irrigation is from 30% to 60% during the last six decades and there is corresponding decrease in the surface water usage as in figure 2.1. Water and related statistics, April 2015[2] has reported that out of the total annual water availability of 1,869 Billion Cubic Meter (BCM)/year, the usable water resources of the country have been estimated as 1,123 BCM/year. This is due to constraints of topography and uneven distribution of the resource in various river basins, which makes it difficult to extract the entire available 1,869 BCM/year. This 1,123 BCM/year includes the ground water contribution of 433 BCM/year.

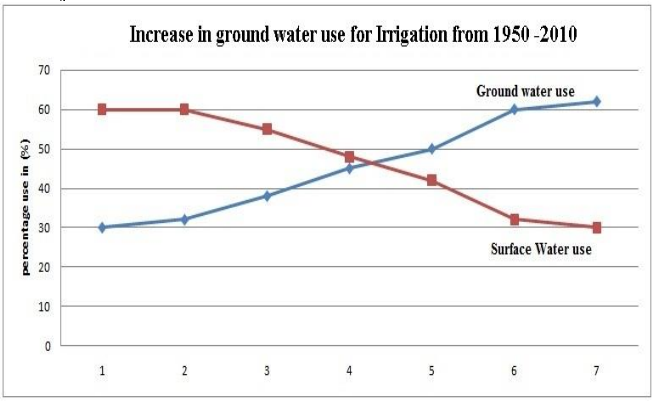


Fig.1 : Increase in ground water use for Irrigation 1940 to 2010[1]

Ground Water Yearbook, India 2013-14, July 2014[3] has reported that the overall contribution of rainfall to the country's annual ground water resource is 68% and the share of other resources, such as canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together is 32%. Due to the increasing population and concentration of population measured in the form of population density rearranges the distribution of ground water potential and becomes the criteria for the efficient implementation of the conjunctive use of surface and ground water strategy.

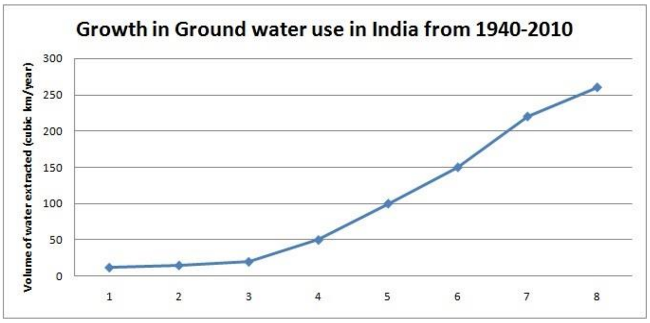


Fig.2 : Growth in ground water use in India From 1940 to 2010[4]

Barker, 2002[4] and Shah, 2009[5] reported that the increase in the ground water usage in India is much higher in the last six decades from 25 km^3/year to 275 km^3/year and this value is less than 100 km^3/year in all other countries as in figure 2.2. Shah, 2002[6], presented that the watershed management approach and externalities that lead to groundwater depletion. Hazell and Fan 2001[7] has reported the Agricultural intensification and localized economic development for increased productivity has influenced the ground water depletion pattern. Rosegrant 2002[8] presented that Irrigation accounts for over 90% of water consumption in India, as in many South Asian countries. Church 2007[9] presented that At a World Climate Research Programme workshop held in 2006, participants highlighted the need for data on changes in subsurface water storage resulting from groundwater use changes and aquifer mining, among other factors.
Hira 2004[10] presented that a major concern of the state is the rapid decline of water-table. About 77 per cent area of the state is facing the problem of falling water table. Marufur Rahman, 2012 [11] Successive depletion of groundwater level with expansion of groundwater irrigation has been discussed from mid 1960s to 2010 in the context of Tanore Upazila. Qureshi 2004[12] presented the importance of conjunctive use to reduce the Ground water depletion.

3. Study Area

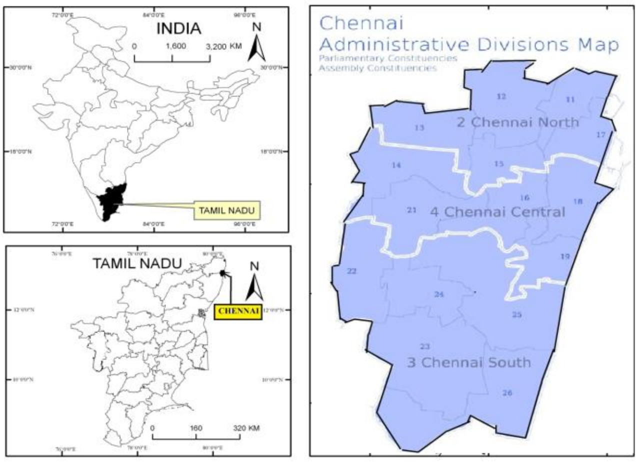


Fig.3: Location map of Chennai city.

Chennai city covers 176 sq.km having terrain slope 1: 5000 to 1: 10000.The Chennai city is in between the latitudes from12.95° to 13.15° and longitudes 80.18° and 80.30°.The city is drained by Coovum river,ADYAR river and KOSASTHALAIYAR river in the north. Major Flood events in CHENNAI city experienced during 1943, 1976,1985,1996,2005 and 2015.
Chennai Metropolitan area (CMA) covers 1189 sq.km and having population more than 86 LAKHS. The CMA falls in the three districts of the Tamil Nadu i.e. Chennai District (area: 176sq.km) and parts of Thiruvallur district (area: 637 sq.km) and Kanchipuram district (arera:376 sq.km). Coovum river starts from Kesavaram anicut in Kesavaram village built across Kortalaiyar river.

4. Research Methodology

A set of observation wells has been maintained by CGWB and Tamil Nadu Water Resources department. Chennai city covers about more than 30 wells. Ground Water level data for all wells are being recorded by the government department at a frequency of one data per one well per one month. These Data are being available for authorized purchase by students and research scholars. The well location map for Chennai city is shown in figure 4.

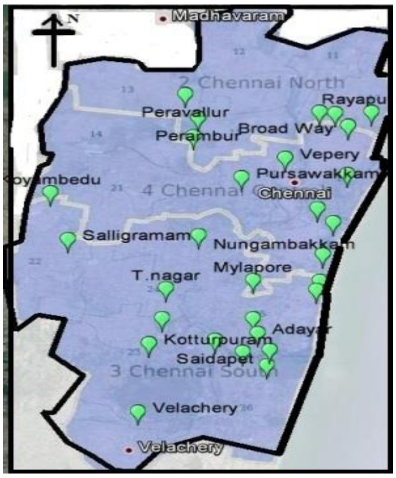


Fig.4: Location map of observation wells in Chennai

The ground water level data was received from Tamil Nadu Water Resources Department for Chennai city during the period of Jan 2016 to Dec 2016.The observed water level from measuring point is used to calculate Depth below Ground Level (DBGL),

DBGL = (Height of water level below measuring point – Height of measuring point above GL)

Absolute Ground water level = (Absolute Ground Level – DBGL)

Both graphical and Statistical methods were used to analyze the time varying ground water level data. A set of graphical plot were prepared individually for each wells and the graph was interpreted. Linear Regression modeling technique has been used to analyze the seasonal ground water depletion pattern for the year 2016. Other curvilinear regression were used for the analysis of long term ground water depletion from 1996 to 2017 using the data provided by CGWB, Delhi.
Linear regression is a modeling in which the expected value of a dependent variable (here it is DBGL) is modeled as a linear combination of a set of explanatory variables. Since the trend of ground water level changes from the month of June as in figure 5 i.e. after the end of summer season, separate linear regression coefficients were determined for duration Jan-May and Jun-Dec and the results were shown in table 1

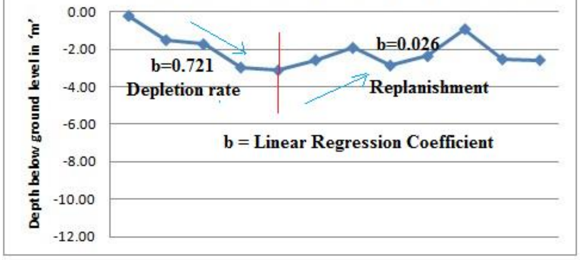


Fig.5: DBGL variations from Jan-Dec 2016 for Nungambakkam location

With the simple Linear Regression model ($y_i = a + b*x + error$) the observed value of the dependent variable y_i is composed of a linear function of a + b*x of the explanatory variable x together with the error. The sample output from Statistical package for social sciences (SPSS) is shown in figure 6 for Nungambakkam well location.

Model Summary and Parameter Estimates

Dependent Variable:VAR00002

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.935	43.456	1	3	.007	.235	-.721

The independent variable is VAR00001.

$DBGL = 0.235 - 0.721 * T$

Fig.6: Sample SPSS output for Nungambakkam well location

5. Results and Discussion

The time varying DBGL plots are shown for selected well locations as shown in figure 7

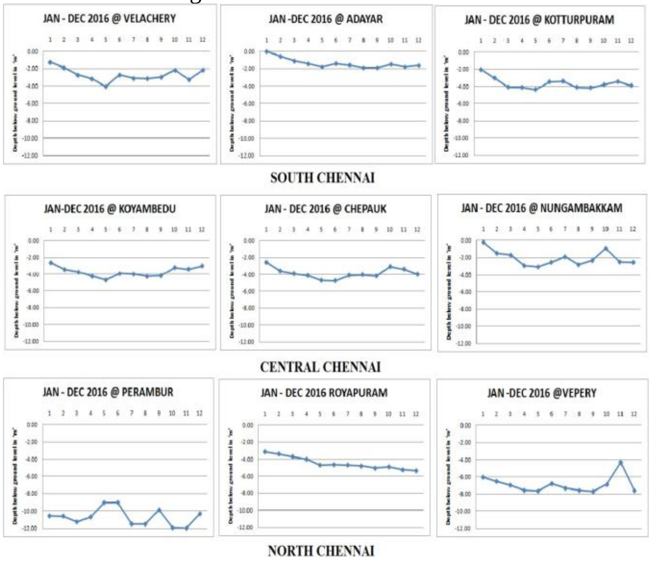


Fig.7: Time varying DBGL plot for selected wells from north, central and south Chennai

It is observed that during the period January to May there is lowering of ground water level. But after the end of summer season i.e. from the month of June the water level gets replenished. The separate regression coefficient for ground water depletion and then the correcting replenishment has been shown in the following table 1. It has been observed that the range of ground water level depletion is from 0.1 m per month at Broadway and up to 0.833 m per month at T.S.Campus locations during post monsoon season from January to May 2016.

Particularly the ground water level at Permabur location was observed consistently 10 m below ground level as shown in Figure 7. A typical comparison regression coefficient of selected wells from each of north, central and south Chennai are shown in figure 8. Similarly the figure 9 shows the seasonal DBGL variations of the selected well group from north, central and south Chennai regions. The Long term DBGL variation across Chennai for various locations is shown in the figure 10.The long term DBGL variation for locations such as Perambur and Vallalar Nagar are shown in figure 11.In both locations there is consistent decrease in ground water level up to a magnitude of about 4 m during the last one decade.

Table 1: Jan-Dec 2016 depletion and replenishment rate in unit 'm / month'

S. No	WELL LOCATION	2016 JAN-MAY GWL Depletion rate (m / month)	2016 JUN-DEC GWL Replenishment rate (m / month)	
1	Velachery	0.683	0.084	Replenishment
2	Adayar	0.241	0.077	Replenishment
3	Adayar Sports Club	0.166	- 0.017	Depletion
4	T.S.Campus	**0.833 (HIGH)**	**- 0.307(HIGH)**	Depletion
5	Saidapet	0.573	- 0.04	Depletion
6	Kotturpuram	0.255	0.061	Replenishment
7	Andra Hopital	0.443	- 0.026	Depletion
8	Saidapet	0.817	- 0.192	Depletion
9	Greenways Road	0.342	0.067	Replenishment
10	T.Nagar	0.681	0.209	Replenishment
11	Nochikuppam	0.352	**- 0.003(LOW)**	Depletion
12	Mylapore	0.274	- 0.012	Depletion
13	Lady Welligton School	0.568	0.05	Replenishment
14	Salligramam	0.338	**- 0.003(LOW)**	Depletion
15	Nungambakkam	0.721	**0.026 (LOW)**	Replenishment
16	Chepauk Pwd	0.471	0.164	Replenishment
17	Govt. Estate	0.497	- 0.109	Depletion
18	Koyambedu	0.498	**0.184 (HIGH)**	Replenishment
19	Pursawakkam	0.249	- 0.246	Depletion
20	Secretariat	0.487	- 0.054	Depletion
21	Vepery	0.426	0.155	Replenishment
22	Broad Way	**0.093 (LOW)**	- 0.012	Depletion
23	Perambur	0.3	- 0.19	Depletion
24	Mint-Stanley Medical	0.319	- 0.173	Depletion
25	Rayapuram	0.365	- 0.117	Depletion
26	Peravallur	0.144	- 0.022	Depletion

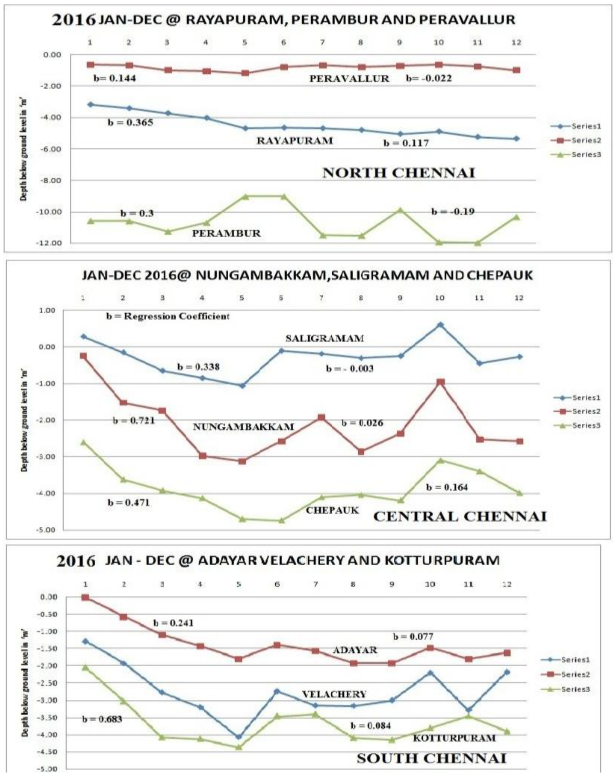


Fig. 8: Typical comparisons of seasonal regression coefficients of selected wells

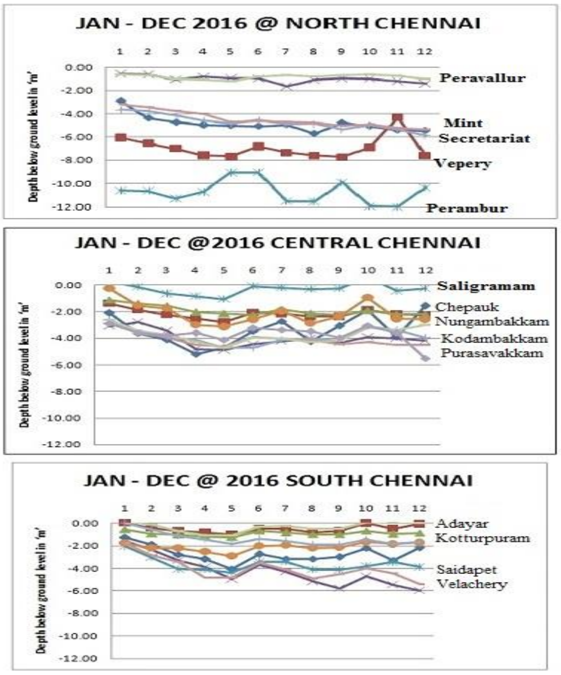


Fig.9: Typical comparisons of seasonal DBGL variation of selected wells

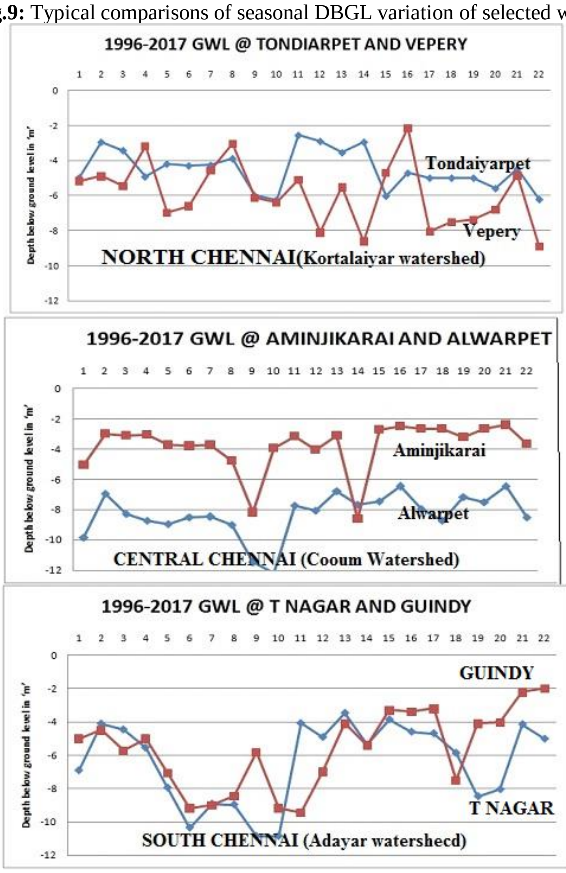
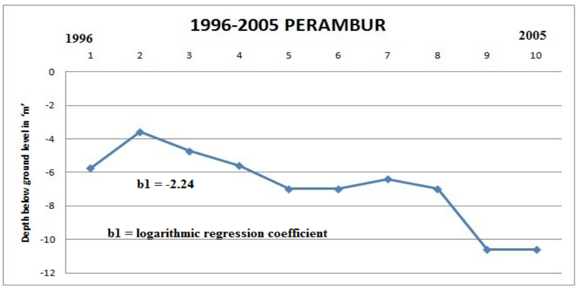


Fig.10: Long term DBGL variation across Chennai



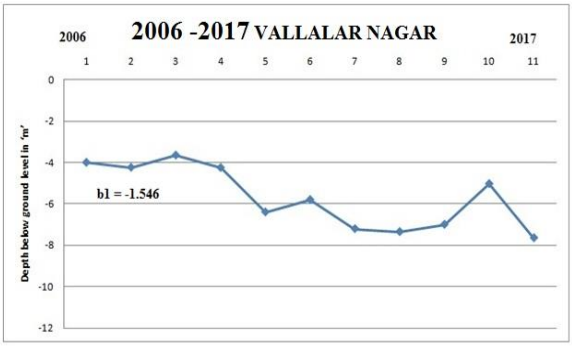


Fig.11: The long term DBGL variation for locations such as Perambur and Vallalar

6. Conclusion

Efficient water resources management practices may be ensured both by structural and non-structural measures. The conjunctive use of surface and ground water is one of the non-structural methods for the optimum usage existing ground water potential in collaboration with that of the surface water. Strategies for the management of conjunctive use of surface water and groundwater resources in semi-arid areas are presented by Quresh, 2004[12] in order to give an approach for optimizing the use of ground water potential and thereby to minimize the ground water depletion rate. Monitoring the ground water depletion rate will help us for efficient decision making during the water management practices. The modeling of ground water depletion rate as function of Characteristics of Aquifer, population intensity and agricultural productivity will be highly useful for controlling the depletion rate in order to ensure the optimum use of water resources potential in a local level as well as in global level.

7. Acknowledgment

The authors are highly grateful to the management of VELS Institute of Science, Technology and Advanced studies (VISTAS) for their consistent encouragement towards this research work and to the Executive Engineer, Tamil Nadu Water Resources Department Chennai, and CGWB, Delhi for their kind support to provide necessary ground water level data for the study area considered.

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