

Estimation of Groundwater Balance of Bailhongal Taluk Belagavi district

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ABSTRACT: The demand of water resources is increasing day by day to keep the food security. The surface water alone will not fulfil the needs of people, so groundwater resources are very much necessary to full fill the people needs and also groundwater is more convenient and less vulnerable to pollution..Rapid urbanization, industrial growth and increasing agricultural production results in over-exploitation of groundwater resources. For sustainable development of groundwater resources, assessment of groundwater resources is necessary. In this study, water table fluctuation methodology, groundwater balance approach and GEC, 1997 Recommendations were used to estimate the groundwater budget for Bailhongal Taluk. The recharge obtained from water table fluctuation method is 8.84m per unit area and stage of groundwater development was estimated as 101%, which represents the groundwater resources fall under over-exploitation category.

KEYWORDS: Groundwater budget, groundwater resources, water table fluctuation, GEC'1997 norms, stage of groundwater development.

I. INTRODUCTION

Groundwater is a very important source of water which fulfils the needs of people such as domestic, industrial and agricultural purposes. This is considered as less contaminated water as compared to the surface water resources. The increasing intensities of agriculture from surface water resources alone may lead to rise in water-table which results in water logging problem which adversely effects the crop growth and makes area uncultivable. To overcome from this problem, we have to develop groundwater resources like dug wells, tube wells etc which helps the surface water to infiltrate into the ground and minimizes water logging problem. Groundwater reservoirs are also an important water resource both for the maintenance of natural environment and for human needs. In current years there has been significant importance on incorporated management of surface and groundwater resources in irrigation project areas to supplement the canal provisions and to augment agricultural productivities as well as to control groundwater depletion, water logging and soil salinity (Rosegrant and Svendsen, 1993; National Water Policy, 2002). Groundwater can be regarded as a renewable natural resource if there is a balance between recharge and abstraction of the aquifers [Voudouris 2006]. Rapid urbanisation, industrial growth and increasing intensities in agricultural sector have led to shortage of freshwater in many parts of the world. The increasing demand of water for domestic industrial and agricultural purposes results in over-exploitation of groundwater resource which causes various ill effects such as water table declination and depletion of aquifer storage. These ill-effects were created due to mismanagement and development of groundwater resources. Hence any ill-effects on groundwater resources will adversely effects the economy of the country. To assure the Sustainable development of groundwater resources, the determination of groundwater budget is necessary. In this study, the water fluctuation method, meteorological water budget method and norms of Groundwater Estimation Committee 1997 were adopted for estimation of groundwater balance for Bailhongal Taluk Belagavi District, which has semi-arid climate and people mainly depends on agriculture as their occupation. The area has suffering from following problems such as,

- Water table running down due to over-exploitation of groundwater resources.
- Shortage of drinking water during non-monsoon season.

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- Farmers over-exploiting the groundwater for sugarcane cultivation.
- Uneven distribution of rainfall.

The objectives of this study are,

- To estimate the groundwater recharge for Bailhongal Taluk.
- To bring out the relation between rainfall and recharge.
- To estimate the groundwater level fluctuation during pre-monsoon and post-monsoon.
- To estimate the groundwater balance for Bailhongal Taluk.
- To estimate the stage of groundwater development.

II. LITERATURE REVIEW

Groundwater recharge and discharge are very much important in understanding the hydrological cycle and for management of groundwater resources. To achieve this, Groundwater Budget approach for an entire aquifer system proved to be very effective for sustainable development of groundwater resources both in regional and large scale basis (Cherauer 2004,). In addition, that right determination of the groundwater budget for a basin may be likewise connected with determination about suitability budget calculation strategies. Different strategies need aid used to calculate those groundwater recharge and discharge amount; notwithstanding selecting the best fitting strategy are often was troublesome. Different factors need to be recognized while choosing the methods for estimation of recharge. As stated by Yin et al, groundwater recharge is the key factor in groundwater balance studies, particularly in semi-arid regions. To estimation groundwater recharge they utilized various methods for example, water-table fluctuation, Darcy's theory and the water plan. (Elsheikh et al 2011) carried out groundwater budget study for alluvial aquifer. In this study, the input to the groundwater is mainly characterized by infiltration from surface water, through infiltration from precipitation and while output refers to the evapotranspiration, pumping and underground outflow. This groundwater balance is estimated by considering the annual input and output components and selection of method will also depends on the spatial and temporal scale of investigation, aquifer features, mechanism sought for understanding the accessibility of data of sufficient quantity and quality and spatial and temporal resolution of outcomes. (Flint et al., 2002), in this paper entitled "Estimation spatial and temporal variation of recharge by groundwater balance technique" Getting qualities of net infiltration, groundwater head out time, Furthermore recharge will be necessary toward the Yucca mountain site, Nevada. Examination of water table fluctuation (WTF) is a functional tool for deterring the extent of both short-term and long-term variation in groundwater recharge and has been extensively applied under varying climatic conditions (Gerhart, 1986; Hall and Risser, 1993; Healy and Cook, 2002; Sharda et al, 2006). Chatterjee and Purohit (1997) studied about the dynamic groundwater of India and estimated groundwater resources estimation. The methodology he used was based on the water-level fluctuation technique and empirical norms for recharge estimation. The groundwater utilization was also estimated.

III. MATERIAL AND METHODOLOGY

A. Study area: The area selected for this study is Bailhongal Taluk of Belagavi District and which comes under Malaprabha catchment and which has average geographical area about 1122.4km² with population 3,56,400 according to 2001 census. The average annual rainfall received by this Taluk is about 500mm to 600mm. The occupation of Bailhongal Taluk is agriculture. The crops which are grown in this Taluk are cotton, groundnut, corn, jowar, wheat, maize, sugarcane etc.

B. Methodology adopted:

The methodologies we adopted for this study are,

1. Groundwater Balance.
2. Bring out the relationship between rainfall and recharge using empirical formulas
3. Groundwater Estimation Committee, 1997 norms.

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4. Water Table Fluctuation method.
5. Groundwater budgeting tool.

C. Data required:

Table: 1 Data collected and their sources

Sl.No	Data	Sources
1	Rainfall data	Statistical department of Belgaum District.
2	Groundwater level data	State groundwater board of Belgaum District.
3	Cropping pattern	Agricultural department of Belgaum District.

Table (1) shows the various data and their sources, which are required to calculate groundwater balance for Bailhongal Taluk Belagavi District. Rainfall data is required for estimating the groundwater recharge, groundwater level data is required for estimating groundwater fluctuation and cropping pattern is required for calculating amount of water required for particular crop.

1. Groundwater Balance Approach:

There are many methods are available for assessment groundwater resources and also for the estimation of groundwater recharge such as empirical formulae, water balance approach, and water table fluctuation method. For groundwater resource assessment groundwater balance approach was considered as very effective. In this approach, various components such as recharge from rainfall, sub-surface inflow-outflow, groundwater idraft, recharge from canals and streams, recharge from irrigation water, evapotranspiration losses and groundwater storage changes were considered. [Chandra and Saxena (1975)].By considering the various inflow and outflow components, the groundwater balance equation can be written as,

Inflow- Outflow = Change in groundwater storage.

$$\boxed{R_r + R_c + R_i + R_t + S_i + I_g = E_t + T_p + S_e + O_g + \Delta S} \dots\dots\dots (1)$$

Where.

- R_r** = recharge from rainfall.
- R_c** = recharge from canal seepage.
- R_i** = recharge from irrigation return flow.
- R_t** = recharge from tanks.
- S_i** = influent seepage from rivers.
- I_g** = inflow to the other basin.
- E_t** = evapotranspiration from groundwater.
- T_p** = draft from groundwater.
- S_e** = effluent seepage to rivers.
- O_g** = outflow to the other basin.
- ΔS** = change in groundwater storage.

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But in this project we neglected the recharge from canal seepage and from tanks because in Bailhongal Taluk, the major tanks and canals are not available.

2. Estimation of recharge from rainfall by using empirical formulas.

Krishna Rao developed the following empirical formulas for estimating the groundwater recharge by rainfall,

$$R_r = K(P - X) \dots\dots\dots (2)$$

The following relationships are holds good for different parts of Karnataka.

$R_r = 0.2(P - 400)$ this relationship holds good for area with average annual rainfall 400 to 600mm.

$R_r = 0.25(P - 400)$ this relationship is suitable for area with rainfall between 600mm to 1000mm.

$R_r = 0.35(P - 600)$ this relationship is suitable for area with rainfall more than 1000mm.

Where,

R_r – Recharge from rainfall in mm

P – Average annual rainfall in mm

3. Groundwater Estimation Committee, 1997:

Groundwater Estimation Committee recommended various norms for estimation of groundwater resource development and also suggested the water table fluctuation methodology for estimation of groundwater recharge.

4. Estimation of recharge by Water Table Fluctuation methodology:

The recharge can be calculated by using following formula,

$$R = S_y \cdot \Delta h + P - R_i \dots\dots\dots (3)$$

Where,

R = Groundwater recharge.

S_y = Specific yield.

Δh = Rise in water table during monsoon season.

P = groundwater abstraction during rainy season per unit area.

R_i = return flow from irrigation during rainy season per unit area.

These data's were obtained from groundwater budgeting tool. This tool requires cropping pattern and well data during pre-monsoon and post-monsoon of particular area to estimate the net recharge and discharge amounts, net annual groundwater availability and stage of groundwater development.

5. Groundwater Budgeting Tool:

This tool is considered to be very effective in estimating the groundwater budget and stage of groundwater development by taking the cropping pattern data and water required for particular crop for their growth by considering the number of sample bore wells and open wells of particular area. The obtained from this tool were represented on graph sheet which shows the net recharge and abstraction during monsoon and non-monsoon and also safe extraction.

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IV. RESULTS AND DISCUSSIONS

A. CALCULATION OF GROUNDWATER LEVEL FLUCTUATION:

Table 2: Groundwater level fluctuation calculation by considering number of wells.

Well Code	Village	Latitude	Longitude	Average pre-monsoon groundwater level	Average post-monsoon groundwater level	Groundwater level fluctuation
20214	Chickbagewadi	15.77224	74.68335	10.7375	10.362222	0.375278
20201	Belvadi	15.71891	74.91613	1.272222	0.225	1.047222
020204B	Sangolli	15.71834	74.83419	11.190833	8.701389	2.489444
020207A	M k hubli	15.72528	74.69446	20.74286	12.612619	8.130241
20206	Ambadgatti	15.63833	74.73586	18.90972	18.10994	0.79978
20205	Kittur	15.60083	74.78751	16.91667	12.147878	4.768792
20212	Bailur	15.56473	74.71974	9.590313	7.92888	1.661433
20209	Nesargi (mallapur)	15.90611	74.81029	3.148611	1.311111	1.8375
20208	Sutgatti	15.89029	74.72334	8.273472	5.83832	2.435152
20202	Bailhongal	15.82141	74.85723	3.898529	2.708725	1.189804
020203A	Sampgaon	15.79503	74.75557	9.962353	8.34421	1.618143

Table (2) shows the water levels in various dug wells and bore wells in Bailhongal Taluk during pre-monsoon and post-monsoon season. By taking all these values, the groundwater fluctuation was estimated

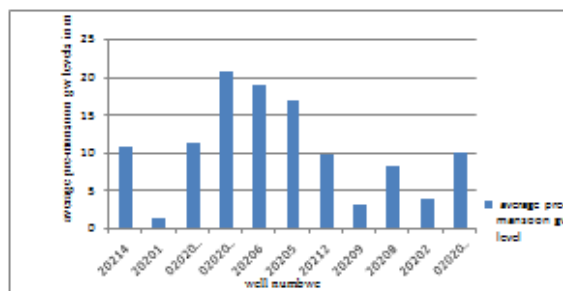


Figure: 1 Pre-monsoon groundwater level variations.

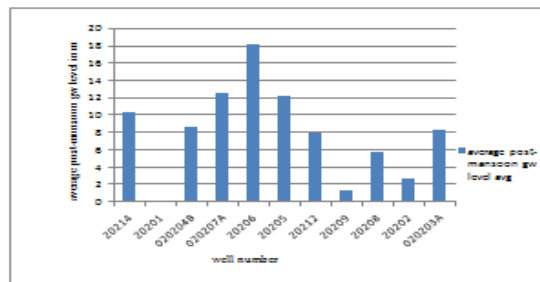


Figure: 2 Post-monsoon groundwater level variations.

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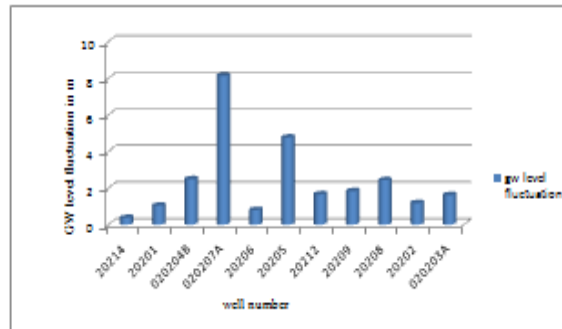


Figure: 3 Groundwater level fluctuation graph

Figure (1), (2), and (3) represents the table (2) calculations by graphs, which show the pre-monsoon and post-monsoon groundwater level variations in graphical format. Figure (3) represents the groundwater fluctuation by subtracting the post-monsoon groundwater level from pre-monsoon groundwater level by considering the 11 wells of Bailhongal Taluk.

B. ESTIMATION OF RECHARGE FROM RAINFALL:

Table: 3 Estimation of Groundwater recharge by rainfall using empirical formulas.

Sl. No.	Year	Average annual rainfall in mm	Average annual recharge in mm	% recharge
1	1960-1961	863	92.6	10.73001159
2	1961-1962	646	49.2	7.616099071
3	1962-1993	712	62.4	8.764044944
4	1963-1964	965	113	11.70984456
5	1964-1965	368	6.4	1.739130435
6	1965-1966	872	118	13.53211009
7	1966-1967	490	18	3.673469388
8	1967-1968	507	21.4	4.220907298
9	1968-1989	556	31.2	5.611510791
10	1969-1970	528	25.6	4.848484848
11	1970-1971	497	19.4	3.903420523
12	1971-1972	497	19.4	3.903420523
13	1972-1973	664	66	9.939759036
14	1973-1974	697	74.25	10.6527977
15	1974-1975	959	139.75	14.57247132
16	1975-1976	517	23.4	4.526112186
17	1976-1977	693	73.25	10.56998557
18	1977-1978	779	94.75	12.16302953
19	1978-1979	1006	142.1	14.12524851
20	1979-1980	788	47	5.964467005
21	1980-1981	990	147.5	14.8989899

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22	1981-1982	568	33.6	5.915492958
23	1982-1983	665	66.25	9.962406015
24	1983-1984	526	25.2	4.790874525
25	1984-1985	449	9.8	2.182628062
26	1985-1986	519	23.8	4.585741811
27	1986-1987	476	15.2	3.193277311
28	1987-1988	609	41.8	6.863711002
29	1988-1989	498	19.6	3.935742972
30	1989-1990	470	14	2.978723404
31	1990-1991	859	114.75	13.35855646
32	1991-1992	618	54.5	8.818770227
33	1992-1993	629	57.25	9.101748808
34	1993-1994	577	35.4	6.135181976
35	1994-1995	409	1.8	0.4400978
36	1995-1996	643	60.75	9.447900467
37	1996-1997	637	59.25	9.301412873
35	1994-1995	409	1.8	0.4400978
36	1995-1996	643	60.75	9.447900467
37	1996-1997	637	59.25	9.301412873
38	1997-1998	694	73.5	10.5907781
39	1998-1999	533	26.6	4.990619137
40	1999-2000	619.6113889	54.90284722	8.860851851
41	2001-2002	465.3316667	13.06633333	2.807961347
42	2002-2003	386.4042727	2.719	0.703667167
43	2003-2004	539.7488889	27.94977778	5.178292786
44	2004-2005	927.4143939	131.8535985	14.21733363
45	2011-2012	417.3	3.46	0.829139708
46	2012-2013	386.2	2.76	0.714655619
47	2013-2014	732.9	83.225	11.35557375
48	2014-2015	514.3	22.86	4.444876531
49	2015-2016	540.1826545	28.03653091	5.190194589

Table (3) represents the relationship between rainfall and recharge and Estimation of recharge from rainfall during year from 1960-2016. The maximum rainfall was takes place during 1977-1978 and it was estimated as 1006mm and minimum rainfall was takes place during 2012-2013 and it was estimated as 386.2mm.

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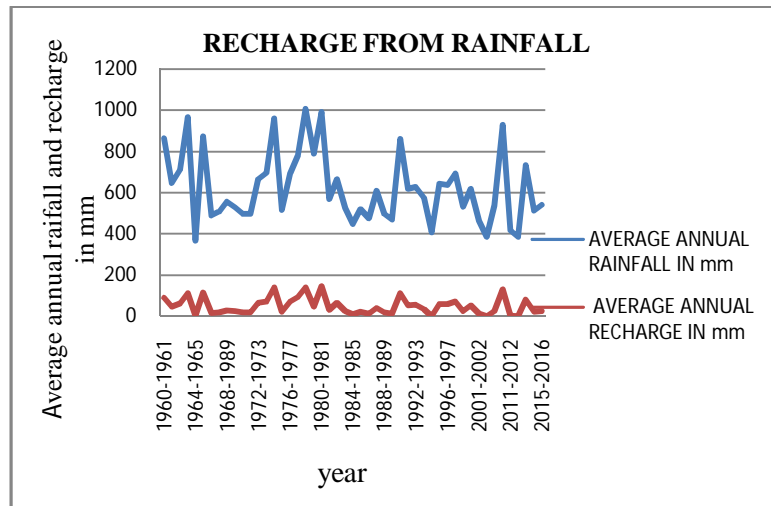


Figure: 4 Yearly variations of rainfall and recharge.

Figure represents the table (3) calculations by graphs from year 1960-2016 for Bailhongal Taluk. In figure (3) blue colour line shows the yearly variation of rainfall and red line shows the yearly variation of recharge.

D. ESTIMATION OF GROUNDWATER BALANCE BY USING GROUNDWATER BUDGETING TOOL:

C.1 Groundwater Budget – Monsoon season [June to October]:

Net Recharge to Groundwater [R1] = 9709068.76×10^3 cub m.

Extraction from Groundwater [E1] = 9835337.26×10^3 cub m.

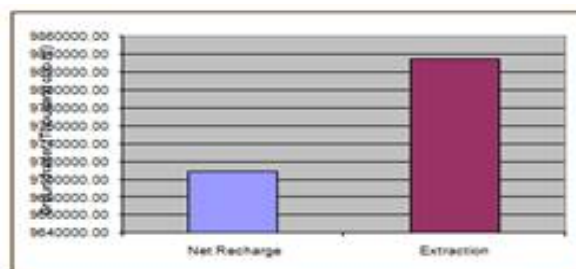


Figure (4): Graph representing net recharge and extraction during monsoon season.

Figure (4) represents the net recharge and extraction amount during monsoon season in the year 2016 by considering the cropping pattern and groundwater level data during monsoon season.

C.2 Groundwater Budget – non- monsoon season [November to May]:

Net Recharge to Groundwater [R2] = 17515438.09×10^3 cub m.

Extraction from Groundwater [E2] = 17629281.28×10^3 cub m.

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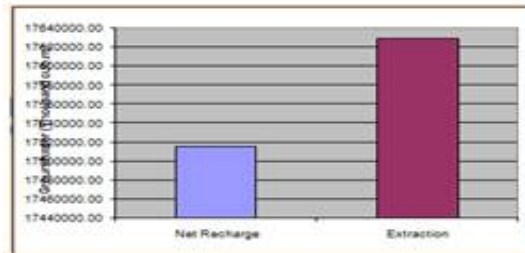


Figure (5): Graph representing net recharge and extraction during non-monsoon season.

Figure (6) represents the net recharge and extraction amount during non-monsoon season in the year 2016 by considering the cropping pattern and groundwater level data of non-monsoon season.

C.3 Annual Groundwater Budget [June to May]:

Net Annual Recharge to Groundwater [R1 + R2] = 27224506.84*10³cub m.

Annual Extraction from Groundwater [E1 + E2] = 27464618.55*10³cub m.

Safe Extraction [70% of net annual recharge] = 19057154.79*10³cub m.

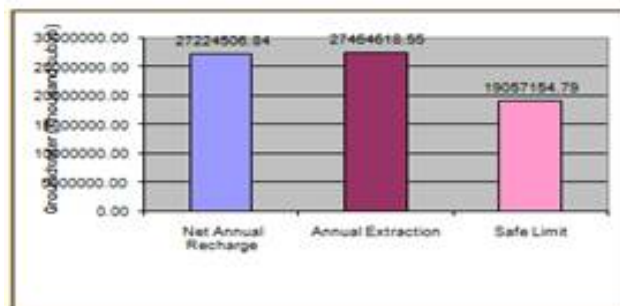


Figure (6): Graph represents net annual recharge, annual extraction and safe limit.

Figure (6) represents net annual recharge, extraction and safe yield during year 2016 by combining the results of both pre-monsoon and post-monsoon groundwater budget.

C.4 Stage of groundwater development:

= [Annual Extraction from groundwater/Net annual Recharge to Groundwater]*100

= [27464618.55*10³cub m. /27224506.84*10³cub m.]*100

= 101%.

D. ESTIMATION OF GROUNDWATER RECHARGE FROM WATER TABLE FLUCTUATION METHOD:

$$R = S_y \cdot \Delta h + P - R_i$$

For Bailhongal Taluk the specific yield (Sy) was considered as 0.1 Δh was estimated from groundwater budgeting tool,

$\Delta h = 1.14\text{m}$.

P was estimated from groundwater budgeting tool

P = 8.76 m.

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Ri was estimated from groundwater budgeting tool.

$R_i = 0.037 \text{ m}$.

$R = 0.1 * 1.14 + 8.76 - 0.037$

$R = 8.837 \text{ m}^3 \text{ per unit area.}$
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V. CONCLUSION

1. The average annual rainfall of Bailhongal Taluk for study period 1960-2016 was estimated as 500mm to 600mm.
2. By considering the water level data from 11 wells in Bailhongal Taluk, the groundwater fluctuation was estimated as 2.46m. and recharge from water table fluctuation was estimated as 8.84m
3. From groundwater budgeting tool the following estimations have been made
 - i. Net groundwater recharge during monsoon = $9709068.76 * 10^3 \text{ cub m}$.
 - ii. Net groundwater extraction during monsoon = $9835337.26 * 10^3 \text{ cub m}$.
 - iii. Net groundwater recharge during non-monsoon = $17515438.09 * 10^3 \text{ cub m}$.
 - iv. Net groundwater extraction during non-monsoon = $17629281.28 * 10^3 \text{ cub m}$.
 - v. Net groundwater budget = $27224506.84 * 10^3 \text{ cub m}$.
 - vi. Net annual groundwater recharge = $19057154.79 * 10^3 \text{ cub m}$.
 - vii. Net annual groundwater extraction = $27464618.55 * 10^3 \text{ cub m}$

From this calculation, the stage of groundwater development has been estimated as 101%, which shows that groundwater is over-exploited in the Bailhongal Taluk, so we have to manage the groundwater resources by reducing the over-exploitation. Groundwater balance estimation approach helps in future development of groundwater resources and their optimal utilization.

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