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A Study on Water Balance in Mylavaram Mandal, Krishna District, Andhra Pradesh, India

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Abstract: Ground water is exploited with little recharge for meeting the increased needs of the society. As a result, the net groundwater availability is decreasing in many parts of the world. There is an urgent need to strike a balance between exploitation and recharge. The groundwater balance status in an academic campus in Mylavaram, Andhra Pradesh is studied for an effective usage period of 225 days in a year neglecting holidays and other vacations. The campus needs water to nearly 5000 members on a daily basis. The campus stretches to an area of 62.5 acres, most of it is pervious. The recharge in the campus is studied based on water table fluctuation method and Rainfall infiltration method suggested by Groundwater Assessment Committee recommendations revised in 2017. The rainwater harvesting potential based on impervious constructions in the campus is estimated. The study indicates that, based on current demand and availability, the net groundwater development is over-exploited. However, recycling of 50% of treated sewage for gardening and lawn sprinkling purposes will improve the condition, reduce the load on groundwater and the development is Semi-critical to critical. Hence, more amount of treated sewage needs to be put to beneficial use to reduce the draft conditions of groundwater. This approach saves money and available groundwater resources. Rainwater harvesting tanks are designed for a storage period of 120 days for making use of the water for gardening in summer.

Keywords: Water balance, Rainwater Harvesting, Groundwater development, Groundwater recharge, Groundwater exploitation

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I. INTRODUCTION

Availability of ground water in adequate quantity and quality is decreasing due to rapid industrial development, urbanization and increase in agricultural production (Singh et al., 2014). The net annual available groundwater availability in India is estimated as 398 Billion cubic meters (Suhag, 2009). A greater emphasis is hence being laid for a planned and optimal utilization of water resources. The world is witnessing higher demands for water while available water resources to the mankind remain almost constant. The damage is becoming worsening due to uneven distribution of rainfall both in time and space. The exploitation of ground water to meet increased demands is deteriorating the water quality and also lowering water table. It is estimated that the per capita availability of water in India is expected to be 1140 m^3 by 2050 from 1869 m^3 as on 2001 with an alarming decrease rate of 39% due to rapid increase of population and its increased needs (Neeru Pragathi, 2019). A water availability of less than 1000 m^3 per capita is considered as stress condition (Simon and Richard, 2017). A comprehensive study of water balancing comprising water availability and water draft will help in proper planning and utilization of water resources.

The average rainfall in Andhra Pradesh as on 2015 status is 940 mm (Neeru Pragathi, 2019) and the ground water table is 15 m deep as on March 2019 (CoreDashBoard, 2019). The state is experiencing a deficit of 479 TMC (17.42 %) of water for a requirement of 2750 TMC. In Krishna district, average rainfall as on 2015 status is 1030 mm (Neeru Pragathi, 2019) and the ground water table is 12m deep as on March 2019 (CoreDashBoard, 2019) in Krishna district. The water required for irrigating 14,35,514 acres of agricultural land is supplied through surface water (Krishna river), major, minor and lift irrigation schemes besides ground water. Despite all these available resources, water deficit of 21.3% in terms of ha-m volume is observed in the district. Similarly, the Mylavaram mandal is experiencing 16% water deficit (Neeru Pragathi, 2019). The deficit is likely to increase due to increase in activities in the mandal after formation of new Andhra Pradesh state. It is in this context, a study of water balance comprising of water availability and water draft is essential and is considered.

Kumar (2013) discussed the need for water balance study and the methodologies to be adopted in this regard. The Ministry of Water Resources, Government of India has developed exhaustive guidelines through Groundwater Estimation Committee in 1997 (GEC, 1997), which were revised in 2017, for computing groundwater flows under several criteria and recommended strategies for estimating ground water development guidelines (GEC, 2017). Chatterjee and Ray (2014) extensively studied the international practices in ground water assessment and suggested few recommendations. They opined that the practices that are implemented in India are comparable to those adopted in other countries but suggested a new approach based on Sustainable Yield Policy, which requires increased and effective application of GIS. Chatterjee and Purohit (2009) extensively discussed the various models used for estimation of ground water potential in India. They estimated that, in AP the number of over-exploited and critical stage areas with respect to ground water usage are 217 and 77, which is alarming.

Pradeep and Srinivas (2009) studied ground water balance in Kurmapalli Vagu basin in AP and concluded that the basin is categorized as Semi-critical in terms of groundwater development as per GEC recommendations. Peera and Kirankumar (2015) successfully studied ground water assessment in Kurnool district using GEC recommendations. Jasrotia and Kumar (2014) studied the ground water usage patterns in Jammu Himalaya region based on GEC-97 recommendations and concluded that the State is under safe category with respect to ground water development. Chinnasamy et al., (2013) used a simulation model using GIS to study the groundwater depletion trends in the northwest state of Gujarat which are compared using primary data from 935 wells and concluded that the results are compatible. Pradhan and Ahluwalia (1986) studied the basin data available during 1980-81 in Bari Doab basin of Punjab and concluded that most of the region in the basin is over-exploited. Suhag (2016) reported a similar conclusion based on 2014 data and observed ground water development in Punjab is 172% which is categorized as Over-exploited based on GEC recommendations. The AP state recorded 37% ground water development indicating safe stage. Adeleke et al. (2015) studied ground water recharge in Ogun-Oshun River Basin in Nigeria and concluded that (i) successful recharge is noticeable in the river basin between 1993 and 2014 and (ii) appreciable correlation existed between rainfall and recharge. Njamnsi and Innocent (2009) evaluated and estimated the groundwater resources of the Zhongmu County China for the period between 1980 and 2007 and suggested a regulatory framework to optimize ground water usage.

1.1 Study Zone

An academic Institution spread in 62.5 acres in Mylavaram village, Krishna District of AP is taken as study zone to conduct water balance studies and assess the rating based on ground water development using GEC recommendations. The campus is located at 40 km from Vijayawada, which is considered as commercial capital of AP and that is located very close (~ 15 km) from Amaravathi, the new capital of AP. The campus, surrounded by the mangroves within the campus, houses 4500 students and 500 staff members of various capacities. The ground water consumption based on the needs of the inhabitants and the ground water recharge based on the land use pattern is studied. The data is used to categorize the campus based on GEC recommendations for its ground water development.

1.2 Objectives

The present study is taken up with the following objectives:

- To assess current water usage in the campus from all sources including administrative, classroom, laboratory and hostels
- To calculate the quantity of current ground water draft
- To calculate the water recharge in the study zone using water balance equation
- To estimate the requirement of rainwater harvesting (RWH) pits based on available data and future demand
- To estimate the quantities and cost for construction of RWH pits in campus
- To compute ground water development in the study zone and categorize it based on GEC recommendations

1.3 Methodology

- Conducting literature review to identify appropriate coefficients and guidelines to be used in the study
- Collection of primary data from the campus with regard to current water usage pattern, water draft, available land use pattern
- Estimation of storm water for the entire campus based on land use pattern
- Estimation of rainfall for computing capacity of RWH tanks
- Computing ground water development for the study zone based on GEC recommendations
- Calculating the capacity, sizing and cost estimation of RWH pits needed in the campus
- Recommending further suggestions

II. EXPERIMENTAL WORK AND MODELS USED IN THE STUDY

The work is carried out in the campus in March 2018. Extensive data is collected in the campus pertaining to current land use, surface area, soil profile, current water usage pattern, water draft to meet the current demands etc. The coefficients to be used in the present study are collected from literature (GEC, 2017) The details are given in Table-1. The available models for assessment of groundwater resources that are used in the present study based on GEC recommendations are discussed below.

Table-1: Data used in the study

S No	Parameter	Value
1	Total area of campus	254950 m^2
2	Total impervious area#	37776.4 m^2
3	Total pervious area	217173.6 m^2
4	Rainfall considered	900 mm
5	Soil type	Red soil with clay content
6	Specific yield	2%
7	Rainfall infiltration factor	0.16

Including buildings, hostel, canteen, parking, roads etc

2.1 Models used in the present study

2.1.1 Rainfall Infiltration model

The recharge from rainfall is computed using the formula (GEC, 2017) as -

Rrf=RFIF x A x (R-a)/1000 ------------- (1)

Where,

Rrf=Recharge from rainfall, ha-m
RFIF =Recharge infiltration factor
A=Area, hectares
R=Rainfall, mm
a=10% of normal rainfall is deducted due to monsoon rainfall

2.1.2 Water Table Fluctuation model

The water storage based on water table fluctuation method is calculated (GEC, 2017) as -

Ds=H x Sy x A + Dg ------------------ (2)

Where,

Ds = difference in water storage, m
H = difference of water table fluctuation from pre-monsoon to post-monsoon period, m
Sy = Specific yield
A = catchment area, acres
Dg = Gross ground water draft

2.1.3 Rain water harvesting potential estimation

The rain water harvesting potential in the study zone is calculated using the formula (GEC, 2017) as -

Total annual RWH potential (m^3) *= Rainfall (m) x Area of catchment* (m^2) *x Runoff coefficient x Filter efficiency -------------- (3.1)*

Area of catchment = Roof Area (m^2) *= Width x Length of Roof --------------- (3.2)*

2.1.4 Estimation of Ground water Draft, Dg

The ground water draft in the study zone is calculated using the formula (GEC, 2017) as -

Unit draft = No of days x No of hours pumping x Discharge ------------ (4.1)

Normalized Unit Daft = Unit Draft x (RF in Year/Normal RF) ------- (4.2)

2.1.5 Recharge from all sources

The recharge of ground water from all sources is calculated (GEC, 2017) as-

$Rrf = h \times Sy \times A + Dg - Rgw - Rwc - R_T$ *------------ (5)*

Where,

Rgw = recharge from ground water irrigation in the area
Rwc = recharge from water conservation structures
R_T = recharge from tanks and ponds

2.1.6 Percentage Deviation

The percentage deviation (PD) of ground water storage between Rainfall infiltration model and Water table fluctuation model is calculated (GEC, 2017) as -

PD = [Rrf (WTF)-Rrf (RIF)) / Rrf (RIF)] x 100 ------------------ (6)

Where,

Rrf = Rainfall recharge

WTF = Water table fluctuation method

RIF = Rainfall infiltration method

Note:

- If PD is greater than or equal to -20%, and less than or equal to +20%, Rrf (normal) is taken as the value estimated by the water table fluctuation method.
- If PD is less than -20%, Rrf (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.
- If PD is greater than +20%,Rrf (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method

2.1.7 Safe Ground water development

The safe ground water development in the region is calculated (GEC, 2017) using the formula -

Ground water development =
(Annual Net Groundwater_Draft /Annual Utilizable Groundwater Resource) x 100

-------- *(7)*

Categorization:

≤ 70%: Safe

>70% and ≤ 90%: Semi-critical

>90% and ≤ 100%: Critical

> 100%: Over Exploited

2.1.8 Allocation for domestic water requirement

The allocation for domestic and Industrial water requirement in mm/year, A is calculated (GEC, 2017) as -

A = 22 x N x Lg --------------- (8)

N = Projected Population density of the sub unit in thousands per square kilometer.

Lg= Fractional Load on ground water for domestic and industrial water supply (≤ 1.0)

III. RESULTS AND DISCUSSIONS

The values are computed using the above models and data given in Table-1. The results are given as follows:

The Rrf is computed using RIF model using Eq (1) as

Rrf = 0.16 x 21.72 x 10,000 x (0.9-0.09) = 28,150 m^3 ------------- (9)

The Ground water Draft, Dg is calculated using Eq (4.2).

Total Ground Water Draft from all sources in campus = 194.32 m^3/day

Number of working days assumed = 225 days

Total ground water draft, Dg=194.5 x 225 = 43,875m^3 ------------- (10)

Net ground water draft, Dg based on current year rainfall in 2018 and normal annual rainfall (CoreDashBoard, 2018) = 43,875 x (827/927) = 39, 142 m^3 --------- (11)

The Rain water harvesting (RWH) potential is calculated using Eq (3.1) as

Surface area of blocks and labs = 13,194 m^2

Impervious coefficient = 0.85 (assumed)

Total RWH potential = 13,194 x 0.85 x 0.9 = 10,107 m^3

Assuming 40% seepage (GEC 2017), the recharge from RWH is calculated as

Rwc = 0.4 x 10,107 = 4043.5 m^3 --------- (12)

The ground water recharge using Water Table Fluctuation Method is calculated based on pre-monsoon and post-monsoon water depth (CoreDashBoard, 2018) using Eq (2) as-

Ds = (11.30-9.03) x (2/100) x 21.72 x 10,000 + 39,142 = 49,003 m^3 --------- (13)

Where h = 11.30-9.03= 2.27 m (CoreDashBoard, 2018)

Recharge from all sources, R is calculated (GEC, 2017) as
$Rrf = h \times Sy \times A + Dg - Rgw - Rwc - R_T$
Where, Rwc = 4043 m^3 and neglecting contributions from other sources
Rrf = 49,003 – 4043 = 44,960 m^3 --- (14)

The Percentage deviation is calculated using Eq (6) as-
PD = (44,960 – 28,150) / (28,150) x 100 = 60% (> 20%) -------------- (15)

Hence, Normal Rrf = 1.2 x 28,150 = 33,780 m^3 ------------------- (16)
Deducting base flow @ 10%, Rrf = 0.9 x 33,780 = 30,402 m^3 ---- (17)
Hence Net Ground water availability = 30,402 m^3 ------------- (18)

Annual ground water draft = 39, 142 m^3
Annual utilizable ground water = 30, 402 m^3
Safe Ground water development = (39,142/30, 402) x 100 = 129% > 100% ----- (19)
Hence Over Exploited.

3.1 Allocation of water requirement:
The allocation for domestic and Industrial water requirement in mm/year, A is calculated (GEC, 2017) as -
A = 22 x N x Lg ------------ (8)
Command area, A = entire campus area = 2,54,950 m^2 = 0.255 km^2
Population, N = 5000 = 5 (in thousands)
Lg = Fractional load on ground water for domestic and industrial water supply (≤ 1.0)
= 0.35 assumed, as no industrial requirement in the campus and only domestic requirement
A = 22 x (5/0.255) x 0.35 = 151 mm
Quantity of water required for domestic usage = 151 x 2,54,950/1000 = 38,498 m^3
Quantity of water required for irrigation (lawn sprinkling) uses = 39,142 – 38,491
= 644 m^3 = 6,44,000 L
For lawn sprinkling usage @ 2.5 L/m^2 area (Punmia et al., 1995),
total area that can be covered = 6,44,000/2.5 = 25,76,100 m^2 > available pervious area of 2,17,173.6 m^2.

3.2 Balancing the demand due to increased needs
But, the needs for domestic requirement are increasing in the campus due to operation of hostels from within the premises. Hence, the sewage generated from the hostels and campus can be recycled and used for lawn sprinkling. Ramakrishna et al., (2018) reported that the sewage generated from the campus requires only primary treatment and can be diverted for lawn sprinkling and greenery development after primary treatment.

Ramakrishna (2007) studied recycling options from a campus of an academic Institution in Rajasthan and concluded that recycling of treated sewage for gardening and lawn development purposes can save enormous amount of groundwater resources.

It is estimated that approximately 27,000 m^3 of sewage is expected to be generated from girls hostel @ 100 lpcd and all the administrative blocks @ 30 lpcd for a total working period of minimum 225 working days excluding vacations and other aspects. If 50% of this sewage is diverted for gardening purposes, a net ground water draft that is expected is = 39,142 m^3 – (0.5 x 27,000 m^3) = 25,642 m^3.

The ground water development can now be worked out for 50% recycling of sewage generated as follows:
Ds = (11.30-9.03) x (2/100) x 21.72 x 10,000 + 25,642 = 35,503 m^3
Hence, Rrf = 35,503 – 4043 = 31,460 m^3 for water table fluctuation method
Now, PD = (31,460 – 28,150) / (28,150) x 100 = 12% (-20 to + 20%)
Hence, Rrf (normal) = 31,460 m^3
Deducting base flow @ 10%, Rrf = 0.9 x 31,460 = 28,314 m^3 ---- (20)
Hence Net Ground water availability = 28,314 m^3 ------------- (21)

Annual ground water draft = 25, 642 m^3
Annual utilizable ground water = 28,314 m^3
Safe Ground water development = (25,642/28,314) x 100 = 91% ----- (22)
Hence Semi critical to Critical.

Since, 50% of ground water pumping is saved for irrigation, ground water now available for domestic uses is 25,642 m^3, which can be used in the campus without any difficulty. In case of shortage, recycling of sewage can be increased to meet the needs. This reduction in pumping can save electricity consumption and subsequently cost.

3.3 Quantity and rate analysis of RWH tanks:

The tanks are designed for a storage period of four months (= 120 days) of dry period. There are five classroom blocks and three lab blocks in the campus. The quantity and cost estimation is made for each of the blocks. The details are given Tables-2 and 3.

Sizing of RWH tank required for class room blocks:

Annual water harvesting potential=1800 x 0.9 x 0.85 =1380m^3
Tank capacity=1380/120 =11.5m^3
Therefore required tank dimensions=6.8m x 2.1m x 1.1m
For five blocks, total volume = 57.5 m^3

Sizing of RWH tank required for lab blocks:

Annual water harvesting potential=4194 x 0.9 x 0.85 =3207m^3
Tank capacity =3207/120 =26.5m^3
Therefore required tank dimensions=7.5m x 2.6m x 1.5m
For all the three lab blocks, total volume = 79.5 m^3

The total volume of all the RWH tanks provided = 57.5 + 79.5 =137 m^3

Table-2: Quantity and rate analysis of RWH tanks for classroom blocks

Description	Item of work	Quantity	Cost/unit (Rs)	Total cost (Rs)
CM(1:6)=1.75m^3	Bricks	4.7m^3	3100	14570
	Cement	(1.75/7) x1440 = 360kgs	50 kg=350	2520
	Sand	(1.75 x 6/7) x1600 = 2400kgs	1ton=2000	4800

Total cost=14570+2520+4800 = Rs 21,890 for one tank.
Total cost for five tanks = 5 x 21,890 = Rs 1,09,450

Table-3: Quantity and rate analysis of RWH tanks for lab blocks

Description	Item of work	Quantity	Cost/unit (Rs)	Total cost (Rs)
CM(1:6)=1.75m^3	Bricks	7.2m^3	3100	22320
	Cement	(2.68/7) x1440 = 548kgs	50 kg=350	3850
	Sand	(2.68 x 6/7) x 1600 = 3675kgs	1ton=2000	7400

Total cost=22320 + 3850 + 7400 = Rs 33,570
Total cost three lab blocks = 33,750 x 3 = Rs 1,01,250
Total cost for installation of rainwater tanks in campus is=1,09,450 + 1,01,250 = Rs 2,10,700
Additional 25% is taken as wastage and labour charges = **Rs 2,63,375**

The campus is currently housing 5 percolation tanks of surface area 12.6 m^2, 14.32 m^2, 13.56 m^2, 16.97 m^2, and 14.62 m^2 making it a total of 72 m^2. They are not sufficient to meet the increased demands. Hence, the RWH tanks are helpful for using the stored water during dry period of 120 days that can be utilized for gardening purpose during lean period.

3.4 Suggestions for improvement

A few suggestions are floated to reduce unnecessary water usage and conserving water at the point of usage (Watersaving tips, 2019, Waterconservation Tips, 2019):

- Fitting the toilets with less water consuming flush tanks
- Periodically checking and servicing the lawn sprinkling systems
- Fitting sensor based taps for automatic opening and closing. Otherwise, open the taps only when necessary and close the water taps as soon as the work is finished.

- Periodically checking and servicing the plumbing systems for any leaks.
- Recycling the wastewater as much as possible. For example, diverting the wash water to plants etc.
- Periodically monitoring the pumps and motors used for pumping for their efficiency and water discharge.
- Applying organic compost and practicing mulching of leaves in the base of trees to effectively hold water.
- Creating awareness among all the people in campus about water crisis situation and encourage them to practice water conservation measures.

IV. CONCLUSION

The groundwater balance between draft and recharge options are studied from an academic campus in Andhra Pradesh, spread in 62.5 acres and housing 5000 members on a working day. The assessment is based on GEC-2017 recommendations available in India. The study revealed that (i) based on current usage and availability the groundwater development is categorized as Over-exploited (ii) recycling of 50% of treated sewage improves to Semi-critical to Critical stage. Hence, more recycling of treated sewage should be used in the campus for gardening purposes. This will save the groundwater resources and money in a long run. Rainwater harvesting tanks are proposed for 120 days storage at an estimated cost of Rs 2.63 lakhs to cater the needs of gardening purposes during lean period. Few suggestions are floated based on providing plumbing fittings for reducing the water wastage.

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