Monitoring the impacts of artificial recharge structures on water table at Ambedkar Nagar,Uttar Pradesh, India

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Abstract

To study the groundwater recharge through rainfall and artificial recharge structures in selected dry well in different locations of UPwas experimented. The data was recorded (1998-2017)to execute the artificial recharge structure at the appropriate locations with best geological condition to enhance the recharge rate at least cost for control of declining groundwater level. Study reveals that the stochastic auto regressive lime series model is an effective tool for management of ground water resource at pre and post monsoon.The variation of pre and post monsoon ground water level is maximum as the physical soil characteristics including hydraulic conductivity may enhance the recharge rate at least cost.

Key words: Hydrological impact, Groundwater recharge, Rainfall recharge, dry well recharge etc.

Introduction

We know that the world as a blue planet, 70% of the earth's surface is covered with water. The reality, however, is that 97% of the total water on earth of about 1400 Billion Cubic Meter (BCM) is saline and only 3 % is available as fresh water. About 77% of this fresh water is locked up in glaciers and permanent snow and 11% is considered to occur at depths exceeding 800 m below the ground, which cannot be extracted economically with the technology available today. About 11% of the resources are available as extractable ground water within 800 m depth and about 1% is available as surface water in lakes and rivers. Out of the 113,000 BCM of rain and snow received on the earth, evaporation losses account for about 72,000 BCM, leaving a balance of about 41,000 BCM, out of which about 9000-14000 BCM is considered utilizable.

Water is a state matter under India's constitution but the central government provides much of the financing for groundwater development in consequence, there is substantial component for control over funding and the interpretation of groundwater data. Historically, most of CGWB-maintained wells were open dug wells. However, a substantial number of isolated piezometers have been installed over the past five years and the number is increasing. Groundwater levels in state networks are generally monitored twice a year, before and after the monsoon. Water scarcity may be severe during droughts or on a seasonal basis even where long-terra trends are absent and water-balance estimation indicate substantial resources are available for development.

Review of Literature:

Agriculture sector is the major consumer of irrigation water in India. Therefore, it becomes very important to develop a water use plan to ensure more crops per drop, thereby increasing water productivity and achieving sustainability in agriculture. In addition, due to erratic and limited rainfall in semi-arid regions, irrigation is essential for increasing crop production and productivity. The reviews relating to surface runoff assessment and groundwater recharge assessment are presented by following below mentioned headings.

1. Ground water exploitation and recharge required
2. Artificial Recharge of groundwater
3. Effectiveness of recharge structures for groundwater development
4. Hydrogeology
5. Rainfall analysis

Globally, groundwater depletion has increased from 126 km^3 in 1960 to 283 km^3 in 2000 Ravichandran *et., al.* (2011).In semi- arid and arid areas, the extraction of groundwater for irrigation was the major cause of groundwater depletion Russo *et., al.*(2014). Bouwer (2002) also observed that groundwater pumping must be managed so that it will not exceed the safe yield or the natural recharge rate of the aquifers and found that it should range from less than 1% of average precipitation in arid to semi-arid climates, to 20% of average precipitation in Mediterranean-type climates and 50% in cool and humid climates as in north-western Europe.Agarwal *et al* (2009) analyzed the problem of declining water table and factors responsible for it in Punjab. They study and found that due to change in cropping pattern irrigation requirement increases, which resulted in over exploitation of groundwater. They suggested suitable strategies for arresting declining water table. Strategies include rain water harvesting, change of cropping pattern, delay in paddy transplantation, and precision irrigation for artificial groundwater recharge. Saha and Marwaha (2016) observed a steep decline in groundwater level in western Ganga plains, India. The average decline rate was about 0.15 m/year. Swami and Kulkarni (2016) also observed that pumping rate was higher than natural recharge in southeastern Nigeria. Due to this, hydrological imbalance had occurred, which was affecting quantity of groundwater.

Groundwater recharge is the downward movement of surface water to join the groundwater. Groundwater recharge may be natural or artificial. Natural recharge takes place naturally without any intervention and human effort. Artificial recharge systems are the engineered systems where surface water is put on or in the ground for infiltration and subsequent movement to aquifers to augment groundwater resources. The work on artificial groundwater recharge started in early fifties. Tripathi *et., al.* (2016) summarized the knowledge on groundwater recharge and reported advances in groundwater recharge estimation technique.

Artificial groundwater recharge began early in last century in the Europe. First infiltration basin for recharging the groundwater was constructed at Goteborg, Sweden in 1897 and subsequently several basins were developed. Niranjan and Srinivasu (2012) assessed “the impact of small water harvesting and artificial recharge interventions in Singoda river basin, coastal Saurashtra, India. They compared the pre-monsoon water levels of the wells located nearer to check dam and far away from the check dam”.

Islam *et., al*. (2014) “estimation and forecast of groundwater recharge and capacity of aquifer are essential issues in effective groundwater resource management in Bangladesh”. Peera and Kumar (2015) assessment “of groundwater resources by whatever method is normally subject to large uncertainties and errors. The methodology recommended by Groundwater Estimation Committee (GEC) is being adopted to compute the groundwater resources in India. The proposed methodology follows the recommendations of Groundwater Estimation Committee, and it uses the water level changes in two specific seasons i.e. one monsoon period and other one is non-monsoon period”.Hao *et., al. (*2014) “groundwater transient flow model was developed to evaluate the applicability and effectiveness of artificial recharge scenarios in the middle-upper part of the Yongding River alluvial fanin Beijing”. “These scenarios were designed by taking into account different types of recharge facilities and their infiltration rate with the Middle Route Project for South-to-North Water Transfer (MRP) as the recharge water source. Khammam District ground water prospects are observed as very good as 511.45 Km2, and poor as 6171.39 Km2 in this Khammam Urban area containing of moderate levels" Mohammad, (2017)."In the present era, groundwater crisis has become a global concern and the magnitude and frequency of groundwater vulnerability have been tremendously increased"Halder (2020).Chatterjee *et. al.* (2020) and Bera *et al.* (2021b) studied that "the climatic variability and cropping pattern have a significant impact over groundwater level but the human encroachment over hydraulic regime and continuous pumping through groundwater is responsible for negative trend of water level".

Mansouri and Mezouary (2015) Showed that "climate change is already a reality affecting, in particular, several countries of the Mediterranean Sea. The impact of this change on water resources is very important; indeed, climate observations highlight periods of droughts and floods, which we call extreme events. To reduce the effect of these two phenomena on the quantitative degradation or lack of water resources due to changes in rainfall, artificial recharge techniques are a solution to adapting to this situation. The excess water generated by floods on watersheds could be retained in basins to be injected into the aquifer reservoir after the identification of suitable sites for groundwater recharge".

Material and Methods:

The study was conducted in the Ambedkar Nagar district UP watershed having area 6628.00 ha. The total area of watershed is 4955 ha and treatable area is 4708 ha.Present study revealed the Artificial ground water recharge by reactivating dry well and catchment-scale of the watershed, to evaluate the effectiveness of individual structures and to delineate the suitable sites for constructing recharge structures in the study area by following key points.

1. Study area
2. Dry well analysis
3. Estimation of ground water recharge
    a. Natural recharge through dry well b. Artificial recharge from structures
    c. From field irrigation d. Water table fluctuation method
4. Effectiveness of individual recharge structure
5. Hydrological impact of recharge structures

6. Delineation of the potential groundwater recharge zones in the study area
7. Model validation with curve number map by using ERDAS software
8. Suggest the site specific suitable recharge structures using RS and GIS

Groundwater recharge estimation using empirical formulae

Natural groundwater recharge from rainfall was estimated using following empirical formulae based on water level fluctuation and rainfall amount in Ganga -Yamuna doab Chaturvedi in 1936 derived an empirical relationship to arrive at the recharge as a function of annual precipitation (Kumar, 1996).

$$R_g = 2\ (P-15)^{0.4}$$

Where,

R_g is net recharge, in inches, P is annual rainfall, in inches.

This formula is useful for preliminary estimates of recharge due to rainfall. This formula later modified by U.P. irrigation research institute.

$$R_g = 1.35\ (P-14)^{0.5}$$

Where R_g is net recharge, in inches, P is annual rainfall, in inches.

Results and Discussion:

Present investigation was carried out to study the artificial ground water recharge by reactivating dry wells. For studying the impact, it is necessary to assess the available water resources such as rainfall, groundwater and details of existing RWH structures. For the assessment of groundwater potential, the groundwater level data of the observation wells situated in the Ambedkarnagar watershed were collected from Ground water department, Ayodhya U.P. The data about the rainfall were collected from Indian Meterological department, Pune.

The main objective of the study is to develop an autoregressive time series model for annual rainfall. The stochastic process of annual precipitation is characterized by an autoregressive model. This chapter discusses about model identification and parameter estimation and evaluation of performance and adequacy of the model by statistical parameters and several other measures such as mean forecast error, mean absolute error, mean relative error, mean square error, root mean square error and integral square error.

The yearly stream flow series Y_t the precipitation was modeled by means of an autoregressive model. The various steps involved are identification, estimation of parameters and validation of model type, sequence and parameters. The general shape of the autocorrelogram and partial autocorrelogram are used as a basis for identification.

1. By using rain water inside the dry well, our water is not going to waste, it is being recharged underground.
2. The quality of underground water is getting better.
3. There is an observation well near our dry well through which we have checked that the ground is getting recharged and the rate of decreasing depth is decreasing.
4. We had installed an observation well near the dry well, then the observation well is telling that the decreasing rate of the ground water level has decreased and has become stable. We have collected rain water, tube well water or canal water inside the dry well similarly. If we keep collecting rain water inside the dry well for 1-5 years in the future then we can improve the water level of our land by doing this the quality of the ground water level will be good.
5. We had installed an observation well there and there we used to test the sample of water in which we saw that there was a difference in the quality of the ground water level the quality is getting better and the recharge rate of the depth in quality is not decreasing much and it is decreasing rate has come down.
6. We analyzed and saw whether we have to save our underground water level or improve the underground water level or do not water or save water from being wasted or save water.

The observed and predicted groundwater level by developed models in each location with R^2 between observed and predicted values and the different statistical parameters and error of predicted values to evaluate the performance of the developed model are given table-1. Autocorrelation and partial auto correlation coefficient for 95 per cent upper and lower limit up to lag 10. The correlation between observed and predicted rainfall is shown in Fig. 1. Tabular values and the graphical representation of the correlation between observed and predicted groundwater levels exhibits strong correlation between observed and predicted which clearly indicates that the auto regressive time series model of order 1 can be used for prediction of groundwater level fluctuations more accurately in Akbarpur Block to adopt the best management strategies within the acceptable limits of errors.

(A) (B) (C) (D)

Picture1 : Drywell recharge work in selected sites of District Ambedkarnagar

Conclusion:

Present study concluded that the autoregressive time series model can be used effectively to predict the pre and post monsoon ground water level.The better predictions will help the Farmers and policy makers to optimally utilize the groundwater resources. It is providing the solutions to execute the artificial recharge structure at the appropriate locations with best geological condition to enhance the recharge rate at least cost for control of declining groundwater level. It reveals that the stochastic auto regressive lime series model is the effective tool for management of ground water resource.

Table -1 Observation and predictionof pre and post monsoon ground water level at different locations of Ambedkarnagar District.

Year	Bevana				Kotwa				Kurki bazar				Rampur sakarwari				Suklahiya			
	Pre		**Post**		**Pre**		**Post**		**Pre**		**Post**		**Pre**		**Post**		**Pre**		**Post**	
	Obs	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**
1998	7.66	6.58	6.55	6.56	3.14	2.04	6.55	6.61	4.03	3.41	6.55	6.72	4.34	3.57	6.55	5.70	3.42	2.68	6.55	6.23
1999	7.37	6.22	6.27	5.85	2.99	1.82	1.90	1.92	3.71	2.97	4.21	4.32	4.71	3.99	6.22	5.30	3.18	2.31	1.70	1.61
2000	7.07	6.13	4.38	4.01	2.78	2.19	2.32	2.36	3.26	3.22	4.23	4.32	4.95	3.89	5.90	5.20	2.78	2.06	2.00	2.05
2001	7.47	6.28	4.40	4.56	4.20	3.19	2.44	2.45	5.45	4.75	2.37	2.43	4.17	3.23	6.48	5.64	3.05	2.17	2.61	2.37
2002	7.02	5.21	6.71	6.08	3.56	3.17	2.06	2.04	3.77	3.64	3.77	3.86	4.22	3.72	6.23	5.64	2.70	2.53	1.55	1.31
2003	5.28	3.60	3.48	3.04	4.95	4.28	1.90	1.89	5.28	4.93	3.48	3.57	5.35	4.30	6.90	6.05	4.50	4.02	1.42	1.15
2004	4.90	3.97	4.02	4.38	4.66	4.20	1.96	1.98	4.90	4.75	4.02	4.15	4.32	4.32	6.31	5.21	4.18	3.17	1.30	1.05
2005	6.60	5.43	7.58	7.87	5.10	4.02	2.31	2.40	5.45	4.90	6.43	6.62	6.62	5.07	5.41	4.33	2.70	1.78	1.33	1.47
2006	6.70	6.07	7.56	8.06	3.65	3.46	2.85	2.88	4.28	3.35	5.95	6.12	3.45	2.15	5.21	4.26	2.50	2.43	2.85	2.79
2007	8.10	6.92	8.49	7.82	5.50	4.99	2.20	2.25	2.75	2.73	5.85	5.99	3.12	2.01	5.54	5.54	4.70	4.66	2.26	2.22
2008	7.29	5.62	3.45	2.78	5.25	4.81	2.50	2.46	5.41	5.15	3.45	3.53	3.47	2.35	8.45	7.62	5.40	4.88	2.30	2.14
2009	5.75	4.47	3.02	2.80	5.35	5.00	1.60	1.55	5.21	5.06	3.12	3.19	3.57	3.26	6.82	6.40	4.35	4.08	1.80	1.59
2010	6.08	5.06	4.96	4.74	5.60	5.06	1.70	1.69	5.54	5.30	3.47	3.55	5.62	5.37	7.57	7.23	4.70	4.37	1.55	1.34
2011	6.86	5.74	5.12	5.29	5.20	4.87	2.00	1.97	5.31	5.18	3.40	3.49	6.41	5.85	8.01	7.39	4.65	4.56	1.55	1.33
2012	6.93	6.39	6.85	6.40	5.60	5.42	1.82	1.69	5.61	5.59	4.00	4.07	5.87	5.93	7.30	7.08	5.25	5.16	1.50	1.60
2013	8.42	6.78	4.28	3.90	6.12	5.51	0.86	0.80	6.05	5.80	1.46	1.48	7.25	6.92	8.30	7.77	5.43	4.87	2.75	2.42
2014	6.27	5.23	4.35	4.67	5.17	4.68	1.70	1.84	5.38	4.91	2.20	2.25	6.69	6.37	7.65	6.40	4.25	3.84	1.20	0.97
2015	6.90	6.28	7.40	7.46	5.20	5.30	3.40	3.37	4.50	4.42	3.10	3.15	6.56	6.93	5.33	5.47	4.30	4.45	1.40	1.47
2016	8.20	7.04	6.55	6.89	6.70	6.44	1.60	1.79	5.60	5.57	1.20	1.28	8.25	7.98	8.80	8.42	5.80	5.71	2.60	2.73
2017	7.40	3.41	7.70	6.25	6.25	3.61	3.90	3.71	6.00	4.12	8.90	9.09	7.15	4.16	8.25	5.15	5.60	3.42	3.00	2.35
R^2 (Bet Obs and Pred)	0.558		0.92		0.788		0.994		0.79		0.999		0.813		0.696		0.807		0.973	

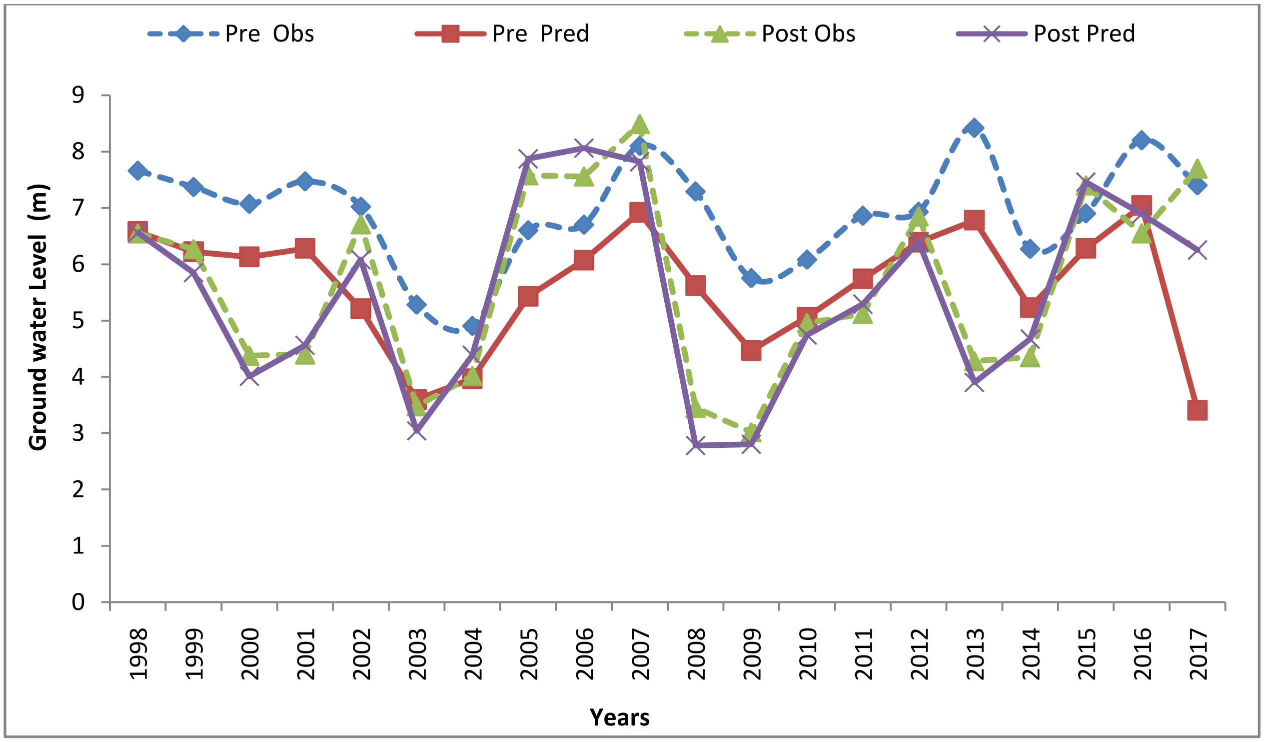

Fig. 1Observation and predictionof pre and post monsoon ground water level at different locations

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