Sustainable development of groundwater: A case study of Begamganj block in Bina River Basin of Madhya Pradesh, India.

Sushant Kumar[1], A.K.Sahu[2], Munendra Kumar[3], M.K. Choudhary[4], T.R.Nayak[5]

[1]Ph.D Research Scholar, Department of Civil Engineering, Delhi Technological University, India
Corresponding author Email Id- Sushantkumar2792@gmail.com
[2]Professor, Department of Civil Engineering, Delhi Technological University, India.
[3]Associate Professor, Department of Civil Engineering, Delhi Technological University, India.
[4]Associate Professor, Department of Civil Engineering, Maulana Azad National Institute of Technology, India.
[5]Scientist E and Head, National Institute of Hydrology, Bhopal, India.

Abstract: **The present study is focused on steady-state groundwater modelling in Begamganj block of Bina river basin in the state of Madhya Pradesh, India. Bina river is a main source of water for the domestical and irrigation supply for the local people. Results provided by the modelling after proper calibration and validation are helpful to identify the water scarce zone which can be further helpful in applying management strategies for meeting groundwater demand for the future need. In this steady state modelling, the top aquifer has been taken into account for the simplification of the model process. Aquifers below the top aquifer were not found suitable in meeting the water quality parameter for domestic usage, as per the norms of Government of India. Management strategies can be applied for the sustainable development of groundwater aquifer in the study area. ILWIS an open source GIS software was used to prepare the required files for the input of Visual MODFLOW. Aquifer data was collected from the data provided by Central Ground Water Board (CGWB) Bhopal, Madhya Pradesh, India and Water Resources Department (WRD) Bhopal, Madhya Pradesh, India. The validation of the model was carried out by matching the field value collected by CGWB and WRD. After identification of water scare zone management tools can be applied for rejuvenation in the aquifer.**

Keywords: **Aquifer, FDM, ILWIS, MODFLOW, Sustainable development, Water resources development**

I. INTRODUCTION

Groundwater is very important due to its good quality and availability. Earlier groundwater was considered safe for domestic use, but recently it is getting depleted in many countries. It is now becoming our need to understand the processes by which groundwater is made available to us. Using mathematical equations, groundwater models can simulate the performance of groundwater system and estimate changes in the water balance caused by pumping, climate, etc. and its affect on groundwater storage, lake levels, stream flow etc. Human activities and natural processes affects the groundwater systems thus require management strategies to keep good condition of groundwater resources. Groundwater management strategies and policy-making should be take account of past and present behaviour of groundwater system, likely response to future changes. Numerical groundwater models have proven to be best predictive tools for managing an aquifers system. These models are used to enhance ground water-resources management. Safe groundwater abstraction and implementing groundwater management is vital key for the sustainability use of it. Begamganj is semi-arid areas and hence facing water scarcity mostly during the dry season. Due to the increase in population and urbanization in the area, over-pumping at inc. Groundwater models have an important role in development and management and in groundwater prediction. With rapid increases in computational ability and ease of access of computers and modelling software, groundwater modelling has become a standard tool for effective groundwater management. In this study, MODFLOW is used to develop a steady state groundwater flow model in Begamganj block of Bina River basin.

II. LITERATURE REVIEW

- **Sushant K et al. (2017)** simulated a groundwater model using MODFLOW for Bina River Basin, Bina, Madhya Pradesh, India. Groundwater Monitoring was the primary concern in this study to identify the water deficit area in the catchment. In this paper, modelling was done with ten-year data of observation well for the year 2009.
- **Graafi et al. (2015)** simulated a model in a natural dynamic steady state that estimated specific yield by modelling only one unconfined layer and it help to access fluctuations in the groundwater level. But the capillary rise of water table has not been implemented which can affect soil moisture, evaporation or even precipitation.
- **Maxwell et al. (2015)** analysed and simulated an integrated model for surface and groundwater interaction under steady-state conditions. They also discussed about imperfection of the model and the difficulties that occurs in a modelling while inputting correct data and its calibration. Their model

represents advancement in understanding of hydrologic scaling in continental river basins.

- **Singhal and Goyal (2011)** developed a conceptual 3-D groundwater flow model Using GMS (Groundwater modeling system) in which spatially distributed recharge values had been utilized as lump sum average of recharge that is normally obtained by method of water budgeting. They used GIS for pre-processing of, geological, hydrogeological and hydrological data. It provided better tools for developing a conceptual model for handling groundwater modelling problems.
- **Zare and Koch (2014)** simulated a groundwater model using MODFLOW of an irrigation/drainage network from 2007 to 2009 by studying groundwater fluctuation. They found that after 10 years of irrigation operation in that land water table will continue to rise and it will result 50% of the plain area to be water logged.
- **Wels (2012)** reviewed benefits of groundwater modelling and its application mainly in Transport modelling, Impact assessment of natural resource. He also described the difficulties involved while modelling groundwater. Results of the calibration process were presented for both steady-state and transient in the form of observed vs. calculated head residuals.

III. DESCRIPTION OF THE AREA UNDER STUDY

The area selected for present study is Begamganj block in Bina River basin of Madhya Pradesh, India. It is located on a river Bina which is a tributary of Betwa River in Bundelkhand region of Madhya Pradesh. Begamganj is a city in Raisen with elevation of 498 metresand having population of 34,031 according to 2011 senses. It is one of the five divisions of Raisen district. Begamganj is located at 23.6°N 78.33°E. Begamganj area in Bina river basin is nearly 91200 ha. The upper part of the study area is highly undulating and covered by forests, barren lands. Later is mostly gently sloping to plain topography largely covered with agricultural fields. The streams are dry after the monsoon months despite enough rainfall. Average annual rainfall recorded for the year 2011 over the basin is 925.3 mm. It has semi-arid to sub-tropical climate. The long-term average (normal) of maximum temperature varies from about 25˚ C in January to 41˚C in May. The wind speed ranges from 170 Km/day in December to 288 Km/day in June. The humidity in these months varies from 91 to 93% in the morning. The average evapotranspiration value of AET was 703 mm/year.

The area around Bina river basin is mostly fertile black cotton soil and some area under red soil. As per the demographic information collected for villages in catchment area, around 40% of area in Rabi season is under wheat cultivation. Gram is grown in around 38% of area cultivated in Rabi. Less than 20% area in Rabi season is under lintel cultivation. The Kharif crops are mostly rain fed and there is no canal irrigation facility. The farmers make their own arrangements to irrigate the crops by pumping groundwater or surface water bodies, in order to save the crops during the dry spell period in Kharif season. The main crops grown in Rabi season are wheat, red gram and main crops grown in Kharif season are soyabeen, urad and paddy Other staple crops like linseed, chickpeas, sorghum, oilseeds are also grown in the study area. Mostly wheat crops grown in the Rabi season are irrigated through the groundwater pumping, as there are limited surface water storage structures, like check dams, tanks, ponds, weirs etc. Therefore, groundwater is exploited for domestic and agricultural uses during Rabi season causing depletion of the water table in most of the area.

IV. METHODOLOGY

A simplified model of the groundwater of Begamganj block of Bina River basin was developed. UTM Projection coordinate system was adopted to generate a general coordinate system for the study area (WGS 84). In this projection system the coordinates can be assigned in metric and geographic units both. ILWIS 3.8.5 software has been used to process all the GIS based data like catchment, Calculation of Area of Blocks of Bina, Digitization of River, Location of well, DEM of Bina. Groundwater recharge occurs naturally due to precipitation from Bina River. Estimating groundwater recharge rate is a elementary prerequisite of proficient aquifer management. The annual average rainfall was taken 925.3 mm in Begamganj block of Bina River basin, Rainfall Data has been taken from State Data Centre, WRD, Bhopal (Madhya Pradesh). The rainfall is a major aspect for the estimating recharge in the area. The pumping well is assigned to each block as per the amount of draft in the area due to data unavailability of pumping wells. Water is abstracted throughout the year from the wells and the abstraction rate of the well was considered to be approximately 800 m^3/day based on the records provided by CGWB and WRD, Bhopal (Madhya Pradesh, India). Ten years of groundwater head level monitoring data were collected from the CGWB and WRD. The groundwater level data from observation wells, recorded by CGWB Bhopal, Madhya Pradesh, India was used to serve model input for the year 2011. Rainfall, ET and soil type are the major factors that affects groundwater recharge. The recharge in the area occurs from rainfall. The recharge in the study area is estimated to be around 30%-40% of rain events.

The hydraulic property plays an important role in subsurface studies and for this study it is derived from aquifer pumping tests carried out by CGWB.. The hydraulic conductivity is not uniform over the catchment. First Aquifer has average hydraulic conductivity K_x and K_y = $2.71X10^{-05}$ m/s K_z=$2.71x10^{-06}$ m/s. The variability in the hydraulic properties are mainly due to heterogeneity. Total porosity is 0.30 for and effective porosity is nearly 0.15. Specific yield (S_y) of aquifer is found out to be 0.11 according to CGWB, Bhopal. Specific storage is calculated by dividing Storage coefficient by the thickness of aquifer layer and average value of S_s in all the wells and it is found out to be $6.46x10^{-05}$ (1/m). For this study area, the static water level records of the wells are obtained from CGWB and WRD, the initial hydraulic heads for the Begamganj blocks of Bina River basin approximately ranges from 8 to 30 meters below ground level. In this Study area Wall Boundary separate groundwater flow from the adjacent watershed in the upper parts of the catchment. The Thickness of wall boundary is interpreted to be 2 m. Finite difference grid of 80 x 80 numbers of Rows and columns are taken into

consideration. The Finite Difference grid size was selected from many by trial runs for maintaining a balance between accuracy of the model and its computational time.

V. MODEL CALIBRATION AND VALIDATION

Model calibration was carried out by hit and trial method and model is validated for the year 2009.

VI. MODELLING RESULTS

The calculated groundwater levels at Begamganj block of Bina was shown to have the satisfactory result as compared to measured levels and the flow patterns obtained indicated that few area was poorly represented by the model.

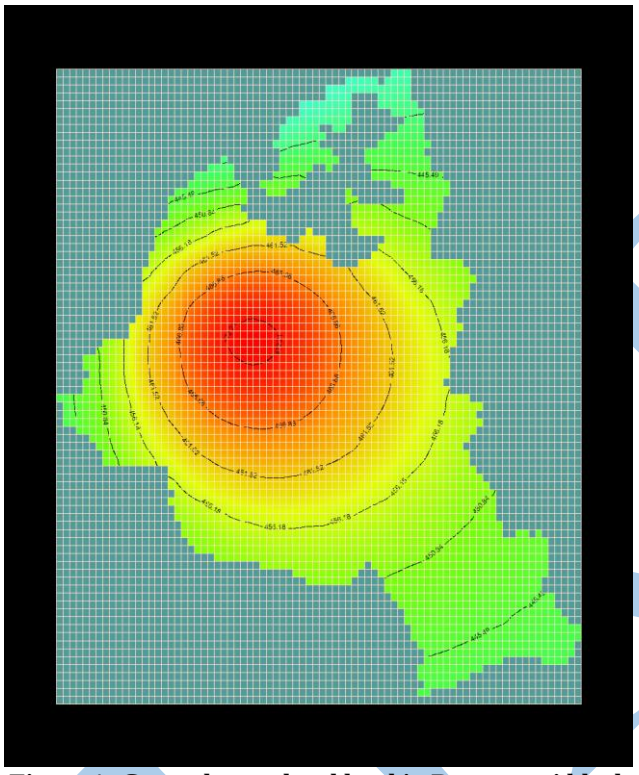

Figure 1: Groundwater head level in Begamganj block of Bina River Basin (in m)

The flow pattern at Bina River watershed can be judged to be reliable since spatial distribution of the soil types at Bina river basin was assumed to be fairly accurate. Along the pathway of the flow through some observation well drainages and pond located were not included in the model and might have influenced the flow pattern.

VII. CONCLUSIONS

Groundwater modelling has become more vital because of its promptly falling groundwater levels because of overexploitation. Groundwater models are important tools which are often used in studying the nature of groundwater flow systems. A groundwater model is an easy representation of the groundwater system of complex nature. It has proven to be very useful tools over the decades for addressing a wide range of groundwater problems and hence supporting the decision-making process. In the present study, a monitoring model is developed to estimate water level of Begamganj block of Bina River basin with the known boundary conditions and the known field observations. GIS was used for pre-processing of hydrogeological, hydrological and geological data. The methodology presented here delivers better tools for a conceptual model development to deal with groundwater modelling problems. The result shows a huge water depletion in the area marked with red colour in Figure 1 as groundwater depletion rates is high in Bina River basin due rising Agricultural and domestic demand due to which a local cone of depression is formed. The groundwater in the basin is exploited for irrigation to the largest because there is no major reservoir and canal water supply in the area. The surface water in the study area is generally available for the beginning of the Rabi season only till the end of December and farmers are dependent on the groundwater pumping from the private dug wells or tube wells. Few number of minor irrigation tanks are available is this basin to supply irrigation water in the Rabi season. During the summer months, almost all villages depend on the groundwater for their drinking and domestic purposes; however pond water is used for live stocks. More water conservation measures are required to maintain the sustainable groundwater in the sub-basin. The development of groundwater resources for sustainable use is greatly dependent on the groundwater model predictions. Hence this study can help in management studies for sustainable groundwater management in the area. The government of India has been extending technical and financial support to the state government for implementing Artificial recharge studies by CGWB the Central Ground Water Board, under the Central Sector Scheme in rural and urban areas of the district but yet at present no such project have been taken. Artificial Recharge is needed the area for efficient groundwater management in the study area.

VIII. FUTURE SCOPE

To obtain a better understanding of general hydraulic properties of the aquifer, additional pumping tests could be taken into consideration. One aspect to understand the groundwater transmission better in the anisotropy porous media. However, note should be taken that when determining the anisotropy, due to lack of data the hydraulic conductivity in the vertical direction was not that accurate. There is a need for improvement in anisotropy. Only the Horizontal conductivity was obtained from the pumping tests. Neither was any grain size analysis conducted for these types of material because no samples were available. It is thus recommended that if future borehole investigations are conducted, a sampling of these materials should be carried out as well. The modelling could perhaps have been better made if Drainage, River boundary conditions could be included. Detail data of River parameters like River Leakance, Thickness, Stage, bottom etc. are required. Drain data was not sufficient enough to apply drainage boundary condition. Nevertheless, a global model has to be relatively correct for a local model to apply and there are still major uncertainties. It is impossible to understand the sub-surface accurately, and the groundwater flow processes. We can construct bores for observation and pumping to monitor water level and other physical features of the system.

IX. ACKNOWLEDGEMENT

We would like to acknowledge the profound sense of gratitude to Dr. Bijendra Kumar Baghel (Scientific officer State Water Resource Data Centre, Govt. of M.P., Bhopal), Dr. Subhash Singh (Scientist D, Central Ground Water Board, Bhopal) and Dr. Surjeet Singh, Scientist D (Groundwater Hydrology Division, National institute of Hydrology, Roorkee) for providing me their valuable time and knowledge.

X. REFERENCES

[1]. Fetter C.W. (2001) "applied hydrogeology" text book 4th Ed. Macmillan College, New York.

[2]. Gebregziabher B (2003) "Integrated geophysical methods to investigate the geological structures and hydrostratigraphic unit of the Aynalem area, Southeast Mekelle" MSc thesis, Addis Ababa University, Ethiopia.

[3]. Graafi I et al. (2015) "A high-resolution global-scale groundwater model" *J. Hydrol. Earth Syst. Sci.*, Vol .19, pp.823–837.

[4]. https://en.wikipedia.org/wiki/Begamganj

[5]. Maxwell R et al. (2015) "A high-resolution simulation of groundwater and surface water over most of the continental US with the integrated hydrologic model ParFlow v3" *J. Geosci. Model Dev*. Vol. 8, pp. 923-937.

[6]. Nayak TR et al. (2015) "GIS Based Mapping of groundwater fluctuations in Bina Basin" J. International conference on water resources, coastal and ocean engineering (ICWRCOE 2015)

[7]. Singhal V and Goyal R (2011) "Development of conceptual groundwater flow model for Pali Area, India" *J. African Journal of Environmental Science and Technology* Vol. 5(12), pp. 1085-1092.

[8]. Sushant Kumar et al. (2017) "Groundwater Modelling in Bina River Basin, India using Visual MODFLOW" Journal IJSRD -International Journal for Scientific Research & Development, Vol. 5, Issue 05,2017, pp. 1398-1402.

[9]. Wels C (2012) "Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities" British Columbia Ministry of Environment, pp.2-289.

[10]. Zare M and Koch M. (2014) "3D- groundwater flow modelling of the effects of the construction of an irrigation/drainage network on possible water logging in the Miandarband plain, Iran". *J. Basic Research Journal of Soil and Environmental Science ISSN 2345-4090* Vol. 2(2) pp.29-39.

