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Groundwater Flow Analysis Using Visual Modflow

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Abstract: *The sustainable use and management of groundwater resources is now a great challenge for many countries of the world. Recently groundwater modelling has been an effective way to address this challenge. There are a number of modelling software exist to simulate groundwater flow. Among them modelling software MODFLOW is used to determine the interactions between the surface water and groundwater and to develop a model for the study area.*
Keywords: *Conceptualization, Groundwater Modelling, ModFlow.*

I. Introduction

Groundwater is a vital source of water throughout the world because of its availability and general good quality. Few years ago ground water was taken as granted for safe use, but recent circumstances indicate that ground water is seriously vulnerable to depletion in some countries. Because of this threat, it is important to understand the processes that make ground water available for use. With the development of groundwater investigations, it is important to understand the development of comprehensive conceptual models and to analytical solutions or numerical methods of groundwater modelling.

II. Study Area

For the present study, Jakkur catchment of Bangalore city was selected. Jakkur catchment is located at latitude 13^{o} 04'0"N to 13^{o} 06'0"N and longitude between 77^{o}35'0"E to 77^{o} 36'0"E and is in the North-East corner of Bangalore city and eastern side of NH-4 covers an area of 18.95 sq.km, the same is seen in SOI toposheet no. 57G/12.The study area is located at the north of Bangalore. Bangalore is the capital of Karnataka state however the district does not have any major river flowing the district falls in Cauvery River basin.

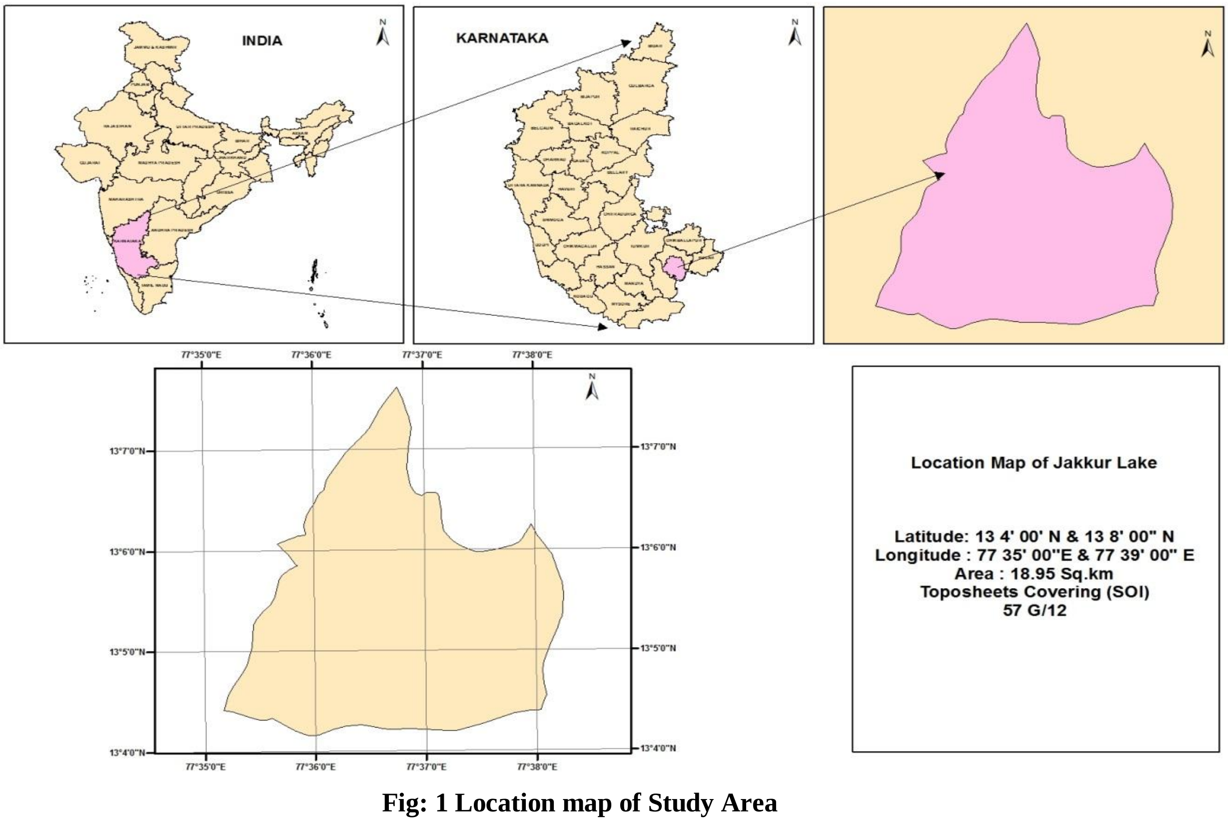

Fig: 1 Location map of Study Area

III. Methodology

Basically, a groundwater model is a simplified representation of the natural groundwater flow system. Without them it would be impossible to evaluate all of the natural processes that impact a hydrogeologic design because of complexities in

- The physical processes that occur in the hydrogeologic environment,
- The spatial distribution of properties and boundaries,
- The temporal nature of the flow system

A model can incorporate all of these complexities, and assess different options and future conditions. The better we can represent these physical features, the better we can predict system response.

Types of Models

- Conceptual models:

1. A mental representation of site geology and hydrogeology
2. Contour plots of groundwater potential

- Physical models, electrical analogues
- Mathematical models

Conceptual Models: It is a hydrogeologist's mental representation of the groundwater flow system.

- The Conceptual hydrogeologic model is the most important step in groundwater model process.
- It forms the basis for developing the numerical model.
- Provide a conceptual understanding of the physical setting related to groundwater flow.
- Integrate multiple data sources.
- Provide a basis for developing the numerical groundwater model.

Numerical Groundwater Models

A numerical model, like Visual MODFLOW, is a mathematical representation of the groundwater environment. It is based on professional interpretation of the available data. It is built in a structured way to provide some assurance that the site-specific model will provide meaningful results.

- The study area consists of six Open Wells (OW) and eleven Bore wells (BW). Latitude, Longitude, Elevation, Fracture encountered, Depth
- of casing, total depth and in case of Open wells diameter is considered. Following table represents the details of Open Wells and Bore wells.

Conceptualisation of Study Area:

To have better understanding on ground water regime of the study area a model is conceptualized, designed and calibrated in Visual MODFLOW. It is a generic model with an objective to quantify the input and output stresses on the aquifer system for a period of 720 days.

Conceptualisation of the study area.

Conceptualisation is used to determine number of layers in the study area as well as the nature of rock and soil present in the study area. The purpose of preparing a conceptual model is to organize the field data and simplify the flow problem with assumptions so that the system can be synthesized and analysed easily. Conceptualisation is done by using MapInfo software which describes the weathered, fractured and massive rocks as well as the casing depth of bore wells.

Conceptual Model and Grid Design

Conceptualing the model of the study area is the most important step in groundwater model process. This is a process of visualisation of different hydrogeological and ground water flow conditions in the study area. It forms the basis for developing the numerical model and provides a conceptual understanding of the physical setting related to groundwater flow

The process of conceptualization helps in determining the number of visualized layers in the study area which are having almost similar hydrogeological setup. The purpose of preparing a conceptual model is to organize the field data and simplify the flow problem with assumptions so that the system can be synthesized and analyzed easily.

The study area was conceptualized in the following manner.

1. The area is visualized into two layers
a. Upper highly weathered and highly fractured – 1st layer
b. Lower fractured hard rock (Granite Gneiss) – 2nd layer
c. Bottom of the second layer is massive hard rock

The Grid size has been decided as 1Km×1 Km. accordingly the whole study area is divided into 42 grids consisting of 7 rows and 6 columns.

Data used

Table-1: Details of Open wells

Well ID	Latitude			Longitude			Elevation (Feet)	Elevation of GL (m)	Dia (m)	Depth (m)
	DEG	MIN	SEC	DEG	MIN	SEC				
OW1	13	4	48.87	77	36	54.6	2937	881.19	7.50	6.6
OW2	13	5	37.13	77	36	33.15	2942	882.69	11.0	6.3
OW3	13	6	15.64	77	36	30.61	2940	882.09	6.50	6.4
OW4	13	5	5.31	77	36	27.85	2944	883.29	11.5	5.8
OW5	13	5	28.33	77	36	15.34	2945	883.40	6.5	8.3
OW6	13	4	26.47	77	36	38.4	2941	882.39	6.3	7.7

Table-2: Details of Borewells

Well ID	Latitude			Longitude			Total Depth (m)	Struck (m)	Depth of casing (m)	Elevation (m)
	DEG	MIN	SEC	DEG	MIN	SEC				
BW1	13	5	43.2	77	36	21.5	139.08	59.04	24	883.025
BW2	13	4	32	77	36	42	136	57.5	25	882.115
BW3	13	4	28	77	37	14	158	69	23	883.675
BW4	13	5	12	77	35	31	155	106	23	888.235
BW5	13	5	14	77	36	2	148	86	22	887.325
BW6	13	6	15	77	36	17	160	84	20	888.435
BW7	13	6	21	77	36	33	174	110	20.4	891.83
BW8	13	7	11	77	36	46	189	140	25.6	898.62
BW9	13	5	17	77	37	18	150	94	21	886.42
BW10	13	5	26	77	37	32	159	78	26	883.145
BW11	13	5	31	77	38	1	162	83	28	889.85

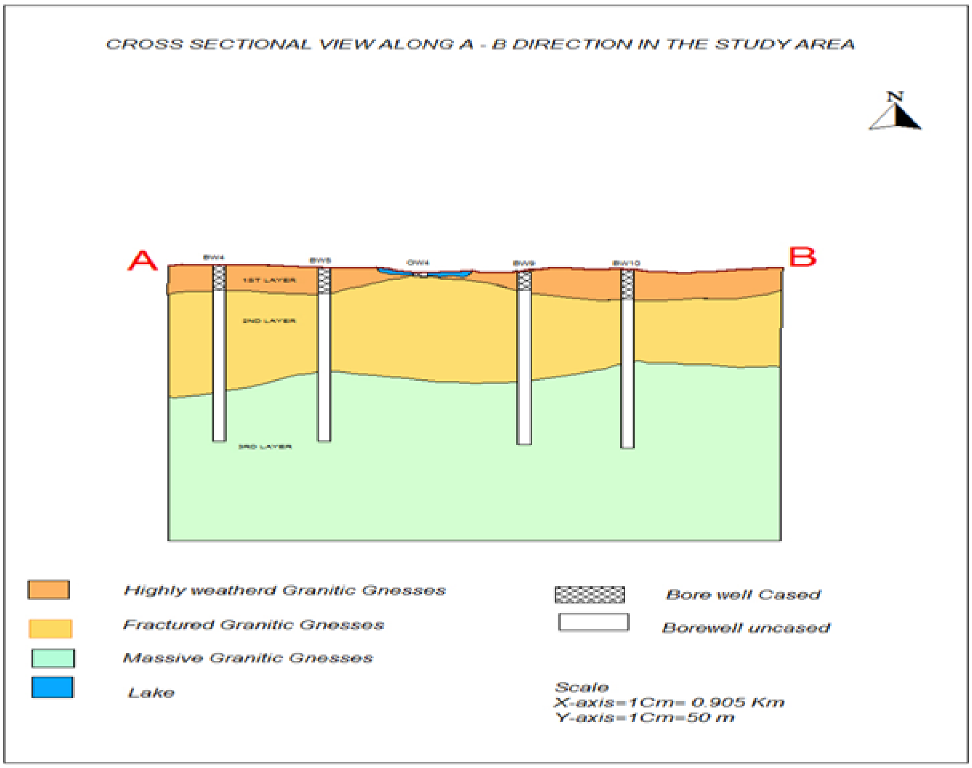

Fig-2: Cross sectional view along A-B in the study area.

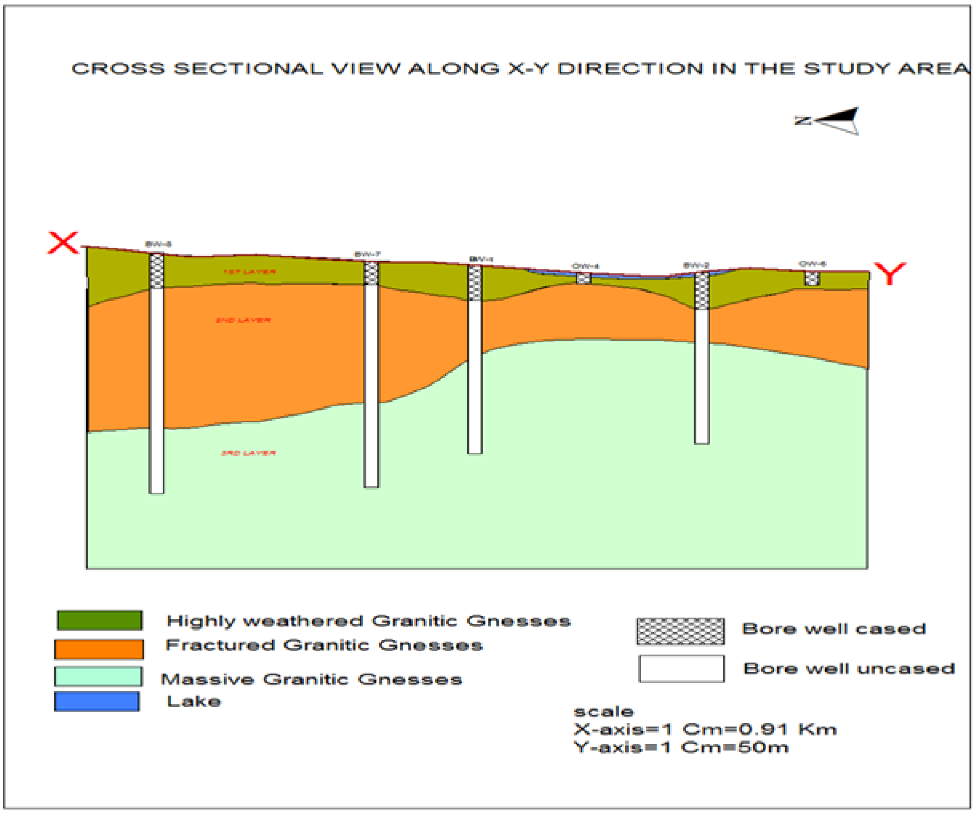

Fig-3: Cross sectional view along X-Y in the study area

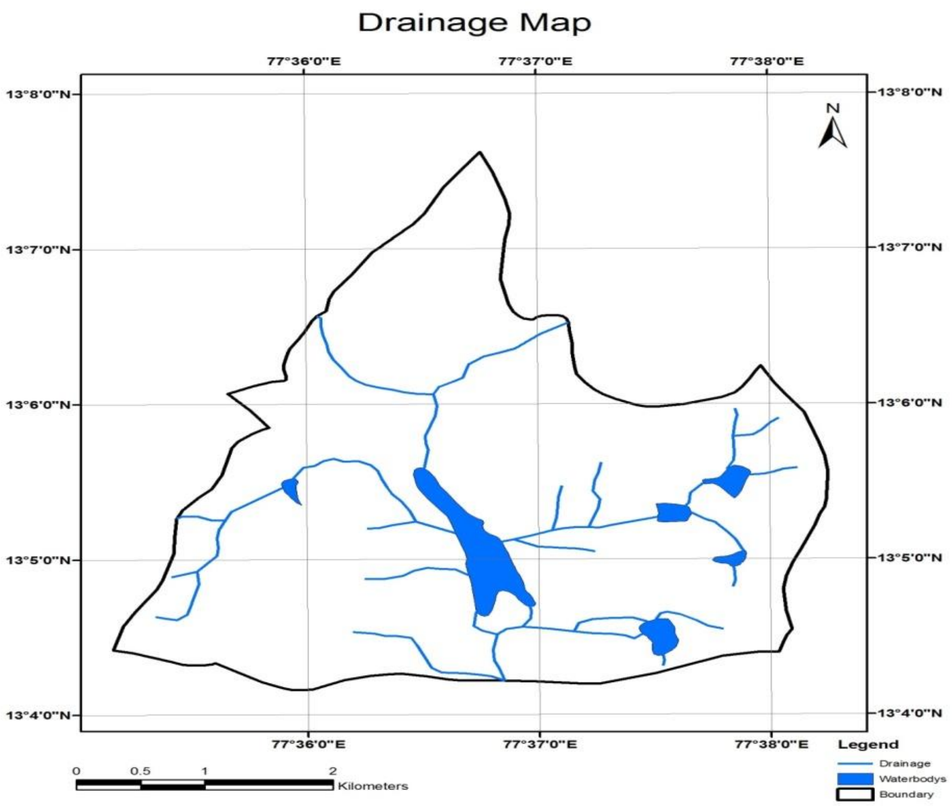

Fig-4: Drainage map of study area.

IV. Conclusions

- The study area, a part of Jakkur River Basin, Karnataka State was chosen for ground water modeling in Visual MODFLOW Pro with the objective to understand the ground water system and to quantify the input and output stresses.
- The external and internal boundaries of the model domain were demarcated. No flow, constant head and river boundary were demarcated. Input parameters like hydraulic conductivity, storage, recharge, draft, evapotranspiration and initial heads were assigned to the model.
- The model was run both in steady state and transient flow conditions.
- The model was calibrated by changing the hydraulic conductivity values by using Trial and Error Method.
- The calculated vs. Observed head indicates the RMS error is 19%, 14 wells falling within the 95% confidence interval.
- Sample Hydrographs of observation wells shows the calculated heads almost (in 50-60% of the wells) matching the observed heads
- The zone budget (recharge versus draft relationship) is obtained from the model shows at the end of stress period 1 the ground water available is – 399 m^3/ day and at the end of stress period 12 (after 720 days) is – 49m^3/day.

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