FORECASTING OF GROUNDWATER QUALITY IN AND AROUND BELLANDUR LAKE BY VISUAL MODFLOW FLEX

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Abstract - Bangalore city originally met its water demand from the lakes and rivers. The lakes and rivers that were once a source of water for irrigation, drinking, fishing is now used as dumping sites for domestic sewage, domestic solid waste. (Ankesh S. B et al., 2018). The lakes of the city are facing extinction due to pollution. Groundwater contamination is nearly always the result of human activity. Human activities like indiscriminate disposal of untreated industrial effluents and sewage wastes, dumping of solid waste, dumping of construction and demolition wastes into water bodies leads to groundwater contamination. One of such lake which is affected by these human activities is Bellandur lake.

Key Words: status of water quality, Bangalore, Bellandur lake.

1. INTRODUCTION

Groundwater is a critical resource for people, economies, and the environment. The increase in population increases the demand and thus the exploitation (Smith et al. 2016). Globally 70 percentage of surface and sub-surface water is used for irrigation India is the largest user of groundwater in the world followed by China and USA. Many regions in India experiencing declining water tables due to over exploitation and ill-management of the resources. According to the recent studies shows that 26% of the area of Karnataka State is under over exploited category. Due to this there is need to understand the processes by which uncontaminated groundwater is made available.

2. OBJECTIVES

The objective of this dissertation work is as follows:

A. To assess the impact of total dissolved solids (TDS) concentration on the groundwater system of Bellandur lake with the help of Visual MODFLOW Flex Software.

B. To predict the future groundwater TDS concentration in the study area from the year 2019 to 2030 using MT3DMS for the following scenarios:

1. If the present scenario of lake pollution without proper control measures continues for next 10 years, what will be the impact on the groundwater quality by the end of 2030

2. If industries meet TDS discharge of 2100 mg/l (IS-10500,2012) and no sewage discharge into the lake for next 10 years, what will be the impact on the groundwater quality by the end of 2030.

3. If the remedial measures such as STP with Integrated constructed wastelands and algae ponds to remove the nutrients meet TDS discharge of 500 mg/l (IS-10500,2012) for the next 10 years, what will be impact in the groundwater quality by the end of 2030.

To suggest remedial measures to improve the future groundwater quality of the study area.

3. Materials and Methodology

Study Area

Location of the study area: Bellandur Lake in Bangalore city spreads across an area of 892 acres. It is located at latitude of 12°58' N and longitude of 77°35' E at an altitude of 921 m above mean sea level. The water storing capacity of Bellandur lake is 17.66 million cubic feet. It is located about 20 km from the city towards the south-east of Bangalore city which is extremely important ecological zone. Water further flows to the Varthur lake, eventually into the Pinakini River basin. The tank remains full throughout the year since it receives sewage water of about 500 MLD from Bangalore city (Ramesh N et al. 2014).

Figure 1: Location of the Bellandur lake.

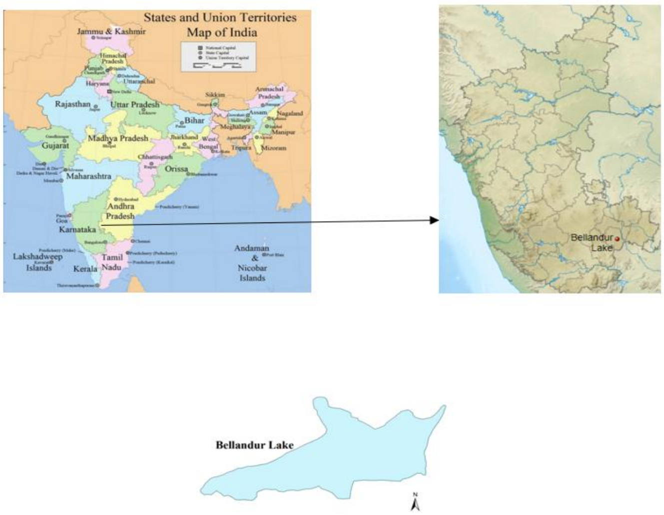

Figure 2: Location of the study area.

Bellandur lake is highly polluted with sewage and in May 2015 the foam covering the water surface caught fire and burned for hours making international headlines. The lake has since caught fire multiple times including in January 2018, and March 2021 but in 1970s people from as many as 18 villages depended on the waters of Bellandur tank to lead their lives.

There are some issues regarding with Bellandur lake because of entry of untreated sewage into the lake through various inlets. Stormwater drains was designed for flow of clean rainwater from Koramangala and Challaghatta (K&C) Valley to Bellandur lake. However, the lake gets sewage inflow due to these reasons.

1) Improper sewage system due to which untreated sewage overflows and joins storm water drains, mixes with rain water, which in turn flows to Bellandur lake.

2) Lack of effluent treatment plants to treat industrial wastes from small factories which also get into the storm water drains (https://bengaluru.citizenmatters.in/all-you-need-to-know-about-bellandur-lake-and-its-problems)

Figure 3: Representation of four main inlets from where sewage enters Bellandur lake. (Pic Source: BWSSB).

4.Methodology

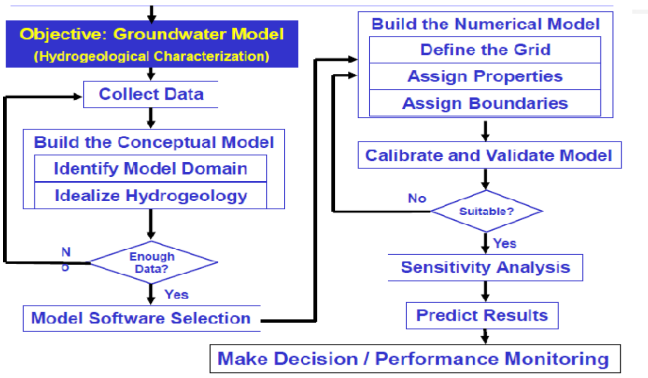

Figure 4: Flow chart of modelling in the schematic block diagram (N.Mondal ,2019)

5. Data analysis and interpretation

Modflow Model input

Preparation of Base Map Base map of the study area was taken from google earth pro. It was converted into .SHP format with the help of ArcGIS.

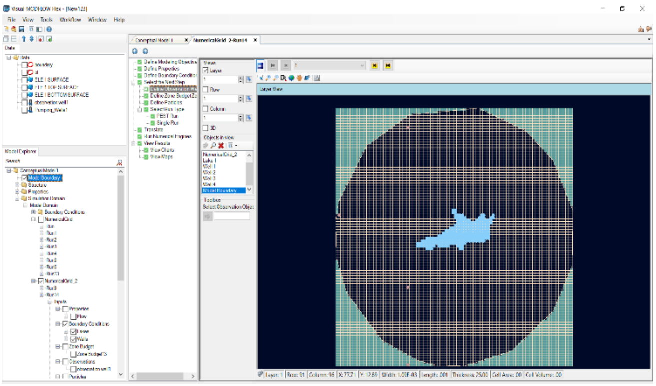

Figure 5: Model Screen with study boundary, lakeboundary and inactive cells

Assigning Layer Elevations (Above Mean SeaLevel): Here three layers were considered throughout the study area. Top erosional ground level (GD) layer, shallow weathering layer as layer-1 and the bottom layer was named as layer-2. The top layer is shallow weathered zone of thickness 25 m and the bottom layer is deeper fractured rock with thickness of 225 meters. By using Google Earth Pro, the elevation data for all layers were obtained. It was entered to the model using the surfer grid file in. GRD format.

- ASSIGNING LAYER PROPERTIES

Visual MODFLOW allows to input field observations for head, concentration and relate these observations to model output values.

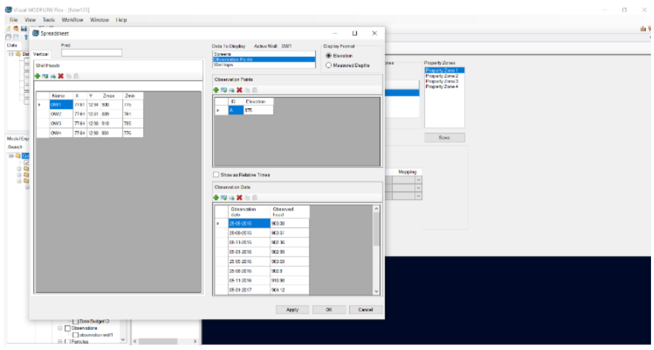

Figure 6: Observation well data being assigned to the model

MODEL RUN- After completing the input parameters, run model isselected from the screen. By selecting [Run] in the Main Menu, Select Run Type dialogue box appears, the modelwas run.

6.MODEL OUTPUT

Modflow output provides graphs of calculated vs observed heads and velocity vectors.

- CHART SHOWING CALCULATED VS OBSERVED HEADS FOR 440 DAYS

The calibrated chart for the 440th day showed good match between the observed head in the field versus the model calculated head values. The standard error of estimation was 1.52 m and the root mean squared value was 2.74 m which implies the error of less than 5%.

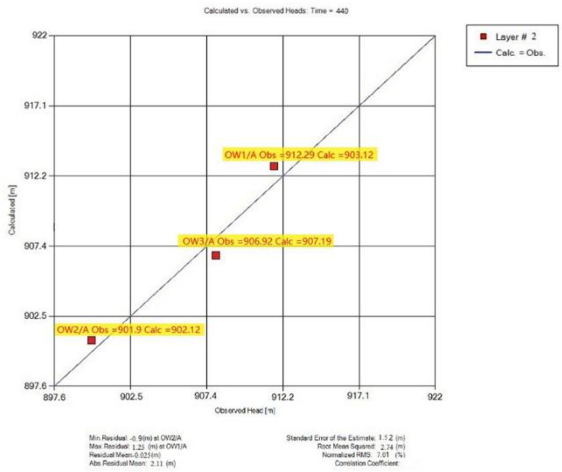

Figure 7: Calculated Vs Observed groundwater level (above MSL) for the 440 days

- CHART SHOWING CALCULATED VS OBSERVED HEADS FOR 880 DAYS

The calibrated chart for the 880th day showed good match between the observed head in the field versus the model calculated head values. The standard error of estimation was 1.08 m and the root mean squared value was 2.74 m which implies the error of less than 5%.

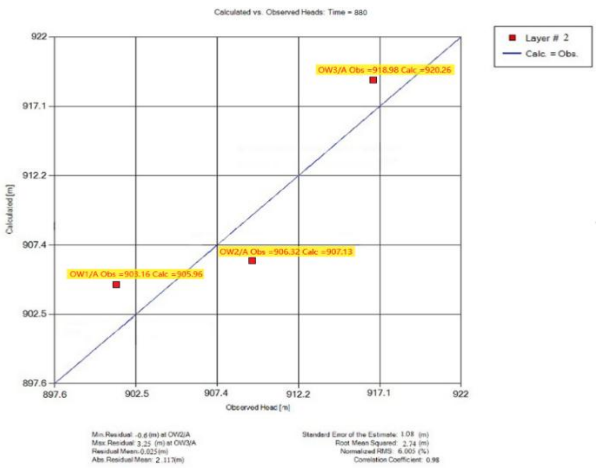

Figure-8: Calculated Vs Observed groundwater level (above MSL) for day 880th day

- CHART SHOWING CALCULATED VS OBSERVED HEADS FOR 1766 DAYS

The calibrated chart for the 1766th day showed good match between the observed head in the field versus the model calculated head values. The standard error of estimation was 1.58 m and the root mean squared value was 2.74 m which implies the error of less than 5%

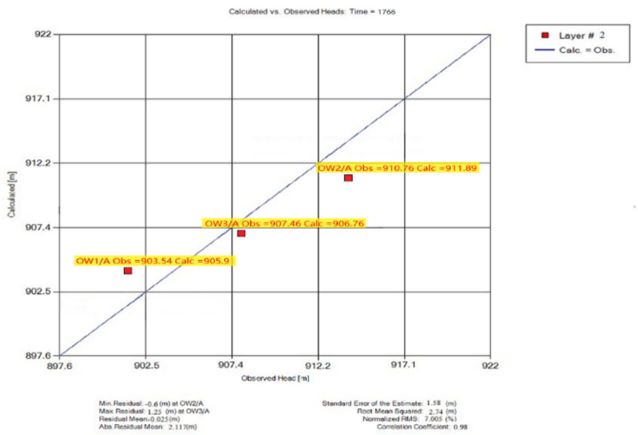

Figure 9: Calculated Vs Observed groundwater level (above MSL) for the 1766 days

7.Modpath Input

Particles are assigned on the boundary of the study area covering source of pollution

Modpath Output

The output from the MODPATH includes the particle path-line direction of the groundwater which was towards the northeast direction of the study area.

8.MT3DMS OUTPUT

MT3DMS output provides calculated versus observed TDS concentration graph.

The Calibration of the model is done by adjusting the dispersion values by trial-and-error method.

- CHART SHOWING CALCULATED VS OBSERVED CONCENTRATIONS FOR 440 DAYS

The calibrated chart for the 440th day showed good match between the TDS concentration that was observed in the field versus the model calculated TDS concentration values. The standard error of estimation was 0.91 mg/L and the root mean squared value was 3.93 mg/L which implies the error of less than 5%

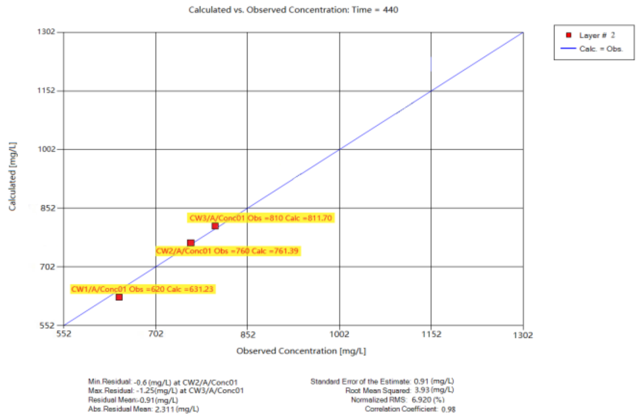

Figure 10: Calculated Vs Observed Groundwater Concentration (mg/L) for the 440 days.

- CHART SHOWING CALCULATED VS OBSERVED CONCENTRATIONS FOR 880 DAYS

The calibrated chart for the 880th day showed good match between the TDS concentration that was observed in the field versus the model calculated TDS concentration values. The standard error of estimation was 0.85 mg/L and the root mean squared value was 2.39 mg/L which implies the error of less than 5%.

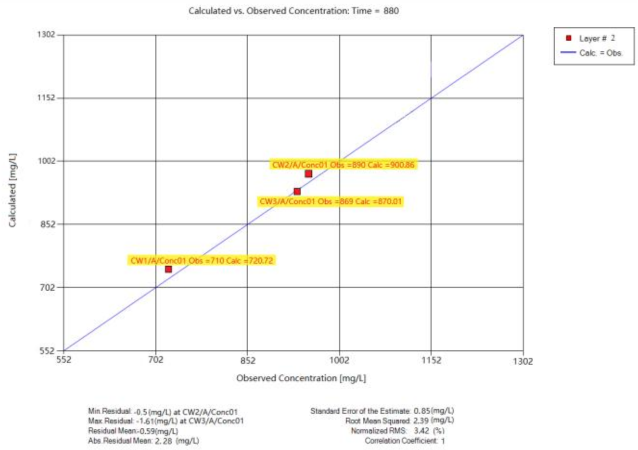

Figure-11: Calculated Vs Observed Groundwater Concentration (mg/L) for 880 days.

- CHART SHOWING CALCULATED VS OBSERVED CONCENTRATIONS FOR 1080 DAYS

The calibrated chart for the 1080th day showed good match between the TDS concentration that was observed in the field versus the model calculated TDS concentration values. The standard error of estimation was 0.91 mg/L and the root mean squared value was 3.93 mg/L which implies the error of less than 5%

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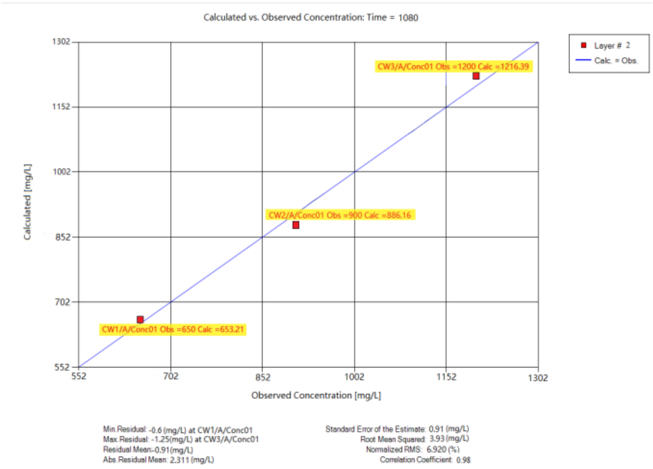

Figure-12: Calculated Vs Observed Groundwater Concentration (mg/L) for 1080 days

9. PREDICTION OF TDS CONCENTRATION IN THE STUDY AREA

The TDS concentration is predicted in the study area under three different Scenario. Prediction is done for 10 years i.e., from the year 2020 to 2030. three wells around to the study area were considered and their impact on the ground water was studied. three wells are located at Adugodi, HSR Layout, Indiranagar.

The three observation wells located at Adugodi, HSR Layout, Indiranagar for the above three scenarios the forecasting is been present in below figures 12,13 and 14 respectively.

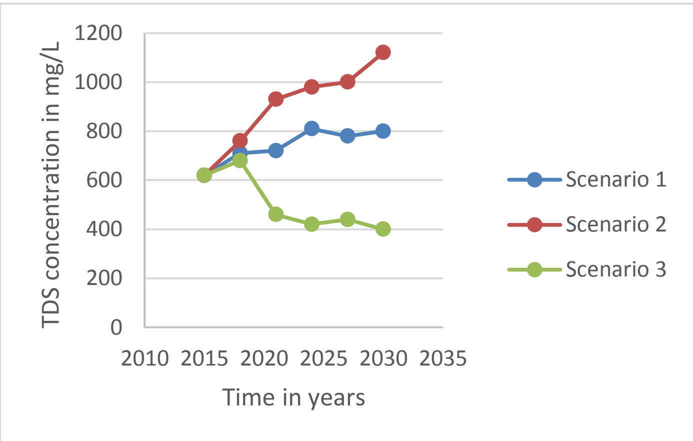

Figure 12: Forecasted values of TDS concentration in groundwater at ADUGODI, till 2030 for all the three different scenarios

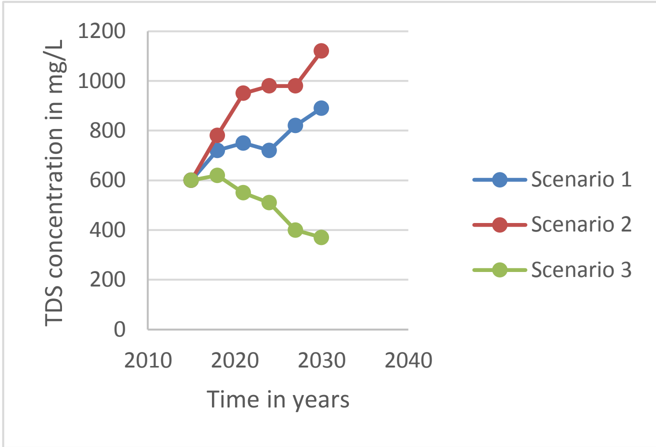

Figure 13: Forecasted values of TDS concentration in groundwater at HSR LAYOUT, till 2030 for all the three different scenarios

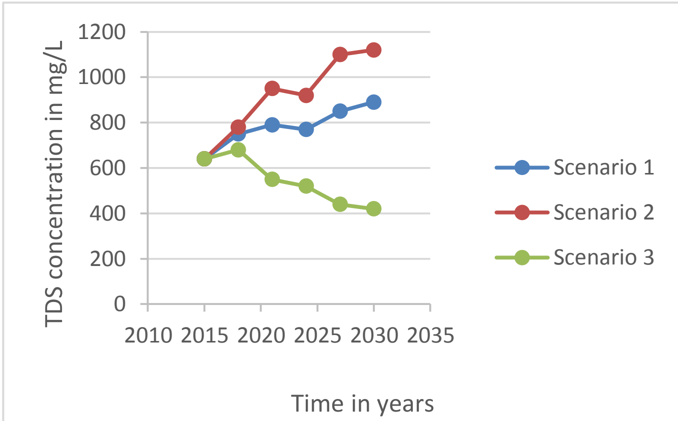

Figure 14: Forecasted values of TDS concentration in groundwater at Indiranagara, till 2030 for all the three different scenarios.

10. CONCLUSIONS

The following conclusions can be drawn from the study based on the results obtained after simulating the model:

- The output from the MODFLOW shows that the head (groundwater level) used for the calibration and the validation step has a good match between observed values and model calculated values for all the three observation wells.
- The direction of groundwater flow is from the South-West to the East direction, following the gravitational flow from the higher elevation in the South west direction towards the lower elevation on East direction of study area.

- The output from the MT3DMS model shows the TDS concentration of groundwater at all the three concentration wells considered to have a good match with the observed and model calculated TDS values for both calibration and validation steps.

- The prediction of the model for the three scenarios are as follows:

  1. The well COBS1 is located in ADUGODI. The borewell is 5.86 kms away from the lake. By the year 2030, if the present scenario continues the TDS concentration will increase up to 800 mg/L. For scenarios 2, the TDS concentration will reach up to 1150 mg/L and for scenario 3 the TDS concentration will decrease up to 400 mg/l.

  2. The COBS2 borewell is located at HSR layout. It is 2.92 km away from the lake. By the year 2030, if the present scenario continues the TDS concentration will increase up to 890 mg/L. For scenarios 2, the TDS concentration will reach up to 1180 mg/L and for scenario 3 the TDS concentration will decrease up to 410 mg/l.

  3. The COBS2 borewell is located at Indiranagara. It is 5.36 km away from the lake. By the year 2030, if the present scenario continues the TDS concentration will increase up to 900 mg/L. For scenarios 2, the TDS concentration will reach up to 1170 mg/L and for scenario 3 the TDS concentration will decrease up to 390 mg/l.

- Predictions for scenario 2, showed that the TDS concentration in groundwater will increase from which it can be concluded that STP are not functioning properly and also improper discharge industrial effluents and sewage water into the lake concludes effect on the ground water system.

- By adopting the remedial measures (scenario 3), it was seen that the TDS concentration had been significantly reduced. Remedial measures that could be adopted are

  1. No more untreated sewage diversion to the lake

  2. Enforcement of Polluter pays Principle which is to ensure zero discharge through effluent treatment plants.

  3. Decentralized treatment of sewage a model similar to Jakkur lake (STP with constructed wetlands and algal ponds)

  4. For frothing and fire issue ban phosphorus use in detergents or regulate detergents with phosphorous in the market which can reduce eutrophication and minimizes the frothing

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