Assessment of Groundwater Pollution from Industries in Agra Region

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Abstract- The present study is aimed at how groundwater quality is being degraded due to the disposal of the industrial effluent in the suburb area of the industry. Agra has many industries and the effluent from the industry causing a serious groundwater trouble. It has reached to an alarming situation as many chemical parameters have already crossed the permissible limit. To understand the movement of the groundwater and contaminant MODFLOW corroborate to be software of great importance and are useful in simulating the exact field conditions which helps to attain the results under different circumstances. MODFLOW is used widely all over the world for the groundwater modelling. A high correlation of chloride (0.935) and bi-carbonate (0.917) was found with Electrical Conductivity, and region is highly under the influence of salinity. Mostly the industries are disposing off their sewage either in river Yamuna or on the land and finally reaching the groundwater table and degrading the water quality of this region. The MODFLOW model simulates the groundwater flow in the region and results shows .81 correlation between the observed data and calculated data at the time period of 1461 days.

Keywords Groundwater, effluents, modelling, correlation, conductivity.

1. Introduction

Earth is called a blue planet. 70% of earth surface is covered by water, only 2.5% of it is fresh water and only 0.1% of that is accessible for direct human use. This is the water that can be found in reservoirs, lakes and rivers and other underground sources that are shallow enough to be tapped at a reasonable cost. Groundwater can be contemplated as the biggest reservoir and natural resource which is easily assessable, it constitutes about 95% of fresh water on our planet. Also Groundwater is protected from the direct intervention of the anthropogenic activities which pollutes it.

The Indo-Gangetic plains of India which includes the area Uttar Pradesh, Bihar contains enormous reserves down to 600m depth also experiences high rainfall and hence recharge is ensured and can support large scale development through deep tube wells.

Development of groundwater has reached a stage of 61% which quantifies to 43 million hectares meter (M ham). Out of which 7 M ham is assigned for domestic, industrial and other uses and rest 36 M ham is allocated for irrigation purposes (ministry of water resources).

Groundwater is being contaminated through natural and anthropogenic activities. Groundwater moving through sedimentary rocks and soil may pick up a wide range of compounds such as magnesium, calcium, chloride. Some aquifers have high concentration of dissolved constituents such as arsenic, boron, and selenium. Natural source of groundwater are affected by type of contaminant and its concentration. Anthropogenic activities such as industrial, agricultural, residential contribute major part in groundwater pollution. Groundwater pollution is governed by water quality testing. Assessing how anthropogenic activities affects the groundwater is pretty useful as it paves the way to minimize the cause of groundwater pollution. Main pollutants that contaminate groundwater are fluoride, chloride, nitrate, sulphate, carbonate, bi-carbonate etc. The other factors which describe the groundwater pollution are Electrical Conductivity, pH, Sodium Absorption Rate. Concluding that the amount of water available for the use, needs to be utilized efficiently. Industries are mainly the prime cause of the groundwater pollution.

Groundwater resource management and its sustainable use can be accomplishes with the help of modelling. Numerical modelling appeared to be a best option to study and replicate the real situations of the complex aquifer and heterogeneous formations of groundwater. And also to predict the future scenarios according to the different conditions. For effective groundwater study its necessary to follow the water balance of the area, for this reason simulations are done to better understand the nature of the hydrology of an area. Tarcan et al. 2010,[1] showed that in Kula vicinity of turkey, the concentration of effluent from the industries in groundwater exceeds the permissible limit but they are not the direct effluents from the tannery industry. Although the study area has high concentration of sodium, sulphate, chloride, and chromium but it was not proposed that this pollution is caused by tannery industry.

Modeling of Yamuna Krishi basin was done by Ahmed and Umar, 2009 [2] where MODFLOW is used for the simulation of basin comprising essential parameters like unlined canal's seepage losses, horizontal flows, return flow from irrigation and rainfall recharge. Groundwater system of Azraq was studied by Sha'r and Hatamleh, 2007 [3] and MODFLOW simulation was done suggesting five different pumping scenarios.

Wastewater from leather industries of Zhejiang province is studied Zhang and Zhang, 2006. Concentration of Ge and NH4+ -N, which are considered the major pollutants from leather industry were found to be 12-13 times greater than the permissible limit. A positive correlation between the released amount of wastewater and concentration of Ge and NH4+ -N indicated increasing pollutant with the increasing amount of water. [4]

Large tannery industry in Dindigul, Tamil Nadu and improper effluent treatment has led to a serious degradation of groundwater in the region. Studies on various parameters such as pH, electrical conductivity (EC), total hardness, total dissolved solids (TDS) and values of some cat-ions (Ca^{2+}, Mg^{2+}, Na_2^+, K) and some anions [$(SO_4)^{2-}$, HCO_3^-, NO_3^- , Cl-)] were conducted. The correlation of 0.99 between EC and chloride, 0.92 between $Mg^{2+}$and Cl^- , 0.87 between Na^{2+} and Cl^- and of 0.86 between Ca^{2+} and Cl^- concludes extensive damage of groundwater by tannery due to excessive use of salt.[5]

Agra is being one of the polluted cities in the Uttar Pradesh. The concentration of each chemical is exceeding the permissible limit. The salinity and the fluoride concentration of the region is much more than the permissible limits. Other parameters like TDS, EC, magnesium (Mg) and sodium (Na) are also above the permissible limit, which in turn contributes to the degradation in the groundwater water quality of the region. The wastewater coming from the domestic sources are being thrown in the Yamuna River or being dumped in any area. There is a lack of pre-treatment before disposal. Industries are disposing off there effluent into the river, which in turn enters into the groundwater system and thus degrading the groundwater quality. There are many industries in the study area which includes leather factories, textile industries.

Waste from leather industry pose critical danger to water, atmospheric and terrestrial systems due to discoloration, high demand of oxygen and toxic chemicals. [6] If the effluents from tannery are discharged without being treated, endangers receiving stream; and percolation in the ground for larger duration seriously contaminates the groundwater table of the area. Major contaminants from tannery are arsenic, chromium fluoride and sulphide. These effluents renders the water unfit for irrigation, general consumption and drinking. The study of quality of groundwater has been done to determine the parameters that are exceeding the normal range.

2. Model Application

The model was developed for the steady-state analysis first and after that it was computed for transient state. Base map was imported from the GIS based shape file to the model screen. The study area was confined to 65660 m x 152099 m. This modelling domain was discretized into 200m x 200 m grid size. Thus the study area is discretized into 40000 cells. The cells of area outside the boundary of the study area was made as inactive. The grid size comes out to be 328m x 760.495m. The grid formation of the study area is given in Fig. 1.

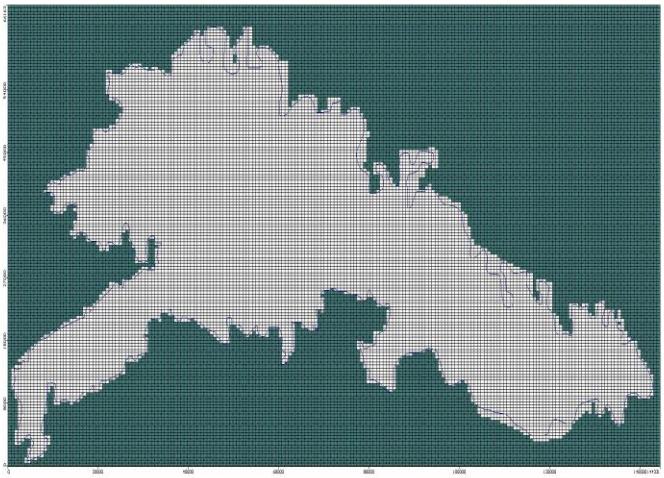

Fig. 1. Base Map of the Study Area

For modeling purpose one layers was considered along the entire stretch of the study area. The elevation was extracted from the DEM of SRTM using Global Mapper. Considering single layer, base of the layer was assumed to be below 90m DEM value. An initial guess is required for head distribution in MODFLOW in the case of steady state simulation. And starting head distribution is required for transient simulation. Initial head is the basis to calculate drawdown and water level future prediction. The data of water level was obtained from Central Ground Water Board

(CGWB) Yearbook 2014-15. [7] The max .and min values are 210m and 117m amsl respectively (Fig. 2).

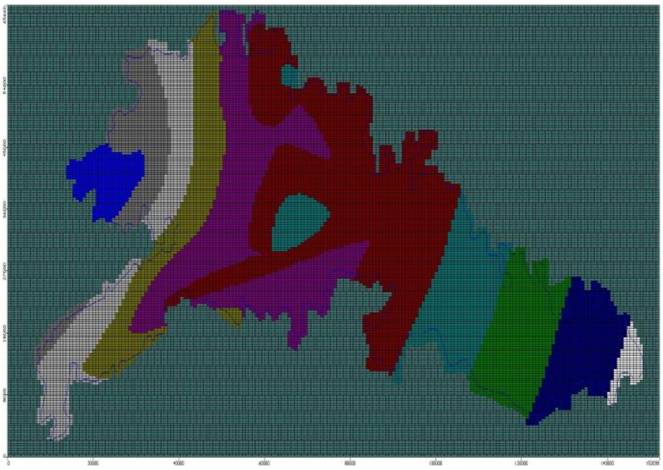

Fig. 2. Depiction of Initial Head

The data is calibrated using the information from the observation well. Drawdown and hydraulic head is saved at every time step. The monitoring of quality of water in 15 bore wells of Agra and groundwater level is done by CGWB quarterly. This observation suggests a rise during July to August (Fig. 3).

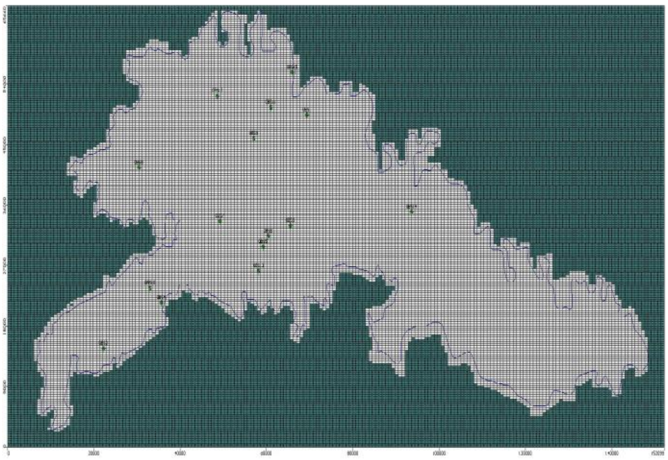

Fig. 3. Observation Well

For the development of the model, boundary conditions is an essential parameter to be applied. Since there are no observation wells on the north-west and south-west side of the area an interpolation of the observation wells was done (Fig. 4). The observation wells of neighboring districts like Bharatpur (Rajasthan), Dholpur (Rajasthan), and Morena (Madhya Pradesh) were used to assign to the boundary condition of the district. Time series data of 2014-16 was extracted from the GIS based interpolation methodology.

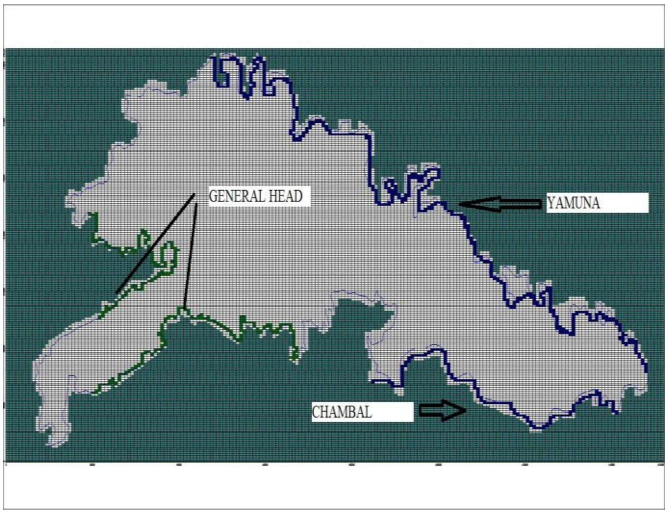

Fig. 4. Boundary Region

731 mm is the annual rainfall in this region. So mostly the recharge of the groundwater is done through the precipitation only. A uniform recharge is considered all over the area annually. Rainfall data is collected from IMD data from 2014-16 (Fig. 5).

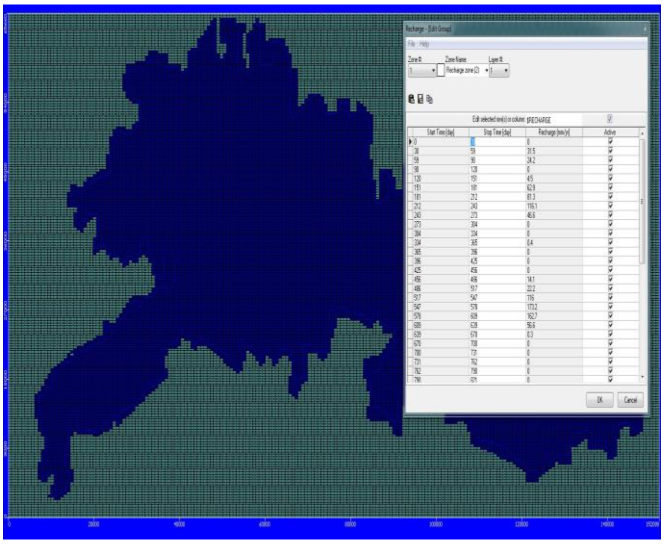

Fig. 5. Recharge

A total of 95255Ham of annual draft is available in the district, 88641 Ham is used for irrigation purposes and 6614 Ham is used for domestic and industrial water supply. 30 wells with an extraction rate of 80950.68 m3/day was observed in the rural areas. 10 wells with an extraction rate of 18120.547 m3/day was observed in the urban area (Fig. 6).

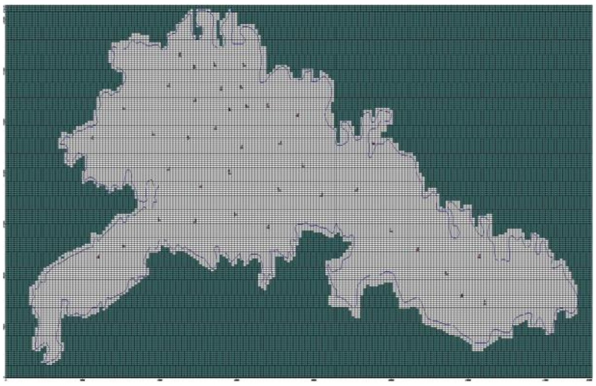

Fig. 6. Pumping Well

3. Results and Discussions

With the help of the Geographic Information System (GIS) software, spatial distribution of different parameters were observed to understand their variation.

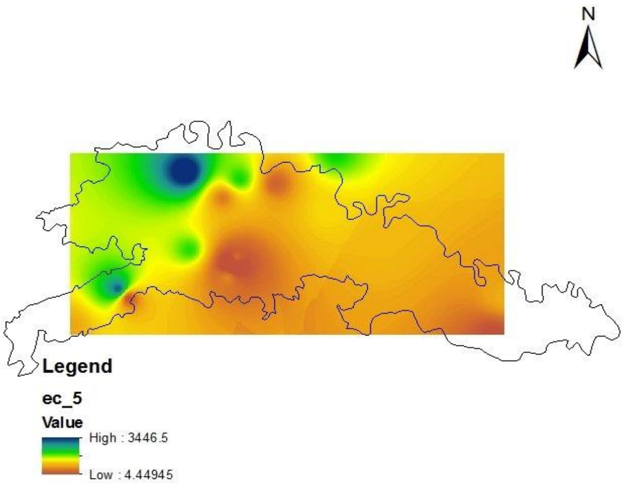

Fig. 7. Spatial variation of EC

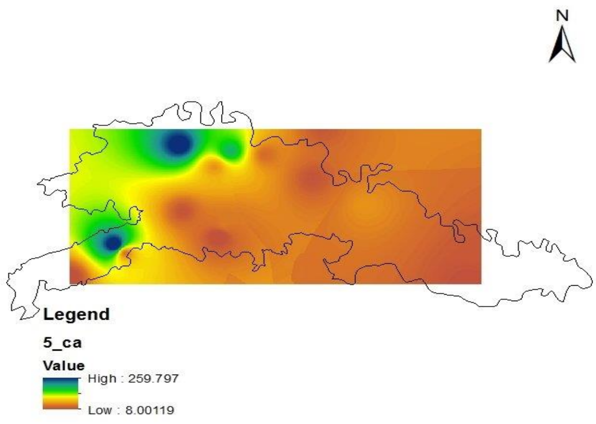

Fig. 8. Spatial variation of Ca

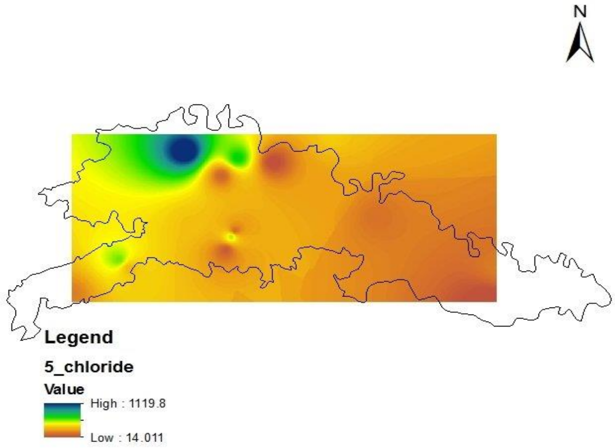

Fig. 9. Spatial variation of Chloride

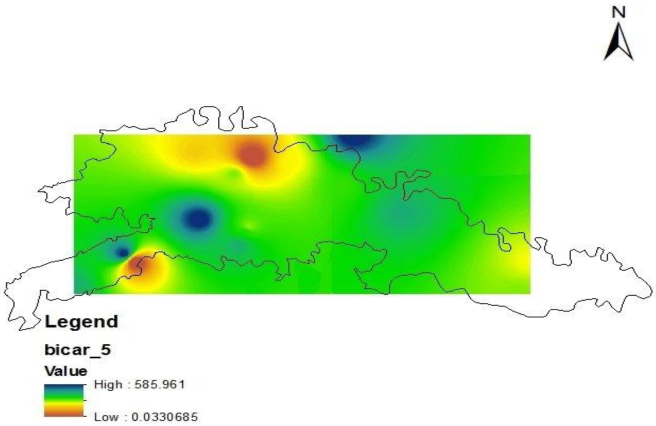

Fig. 10. Spatial variation of Bicarbonate

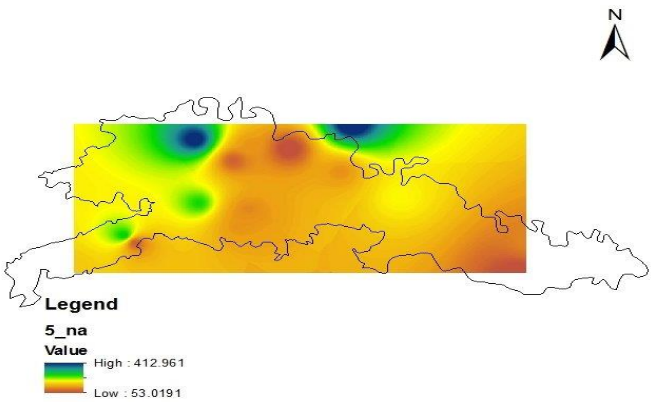

Fig. 11. Spatial Variation of Na

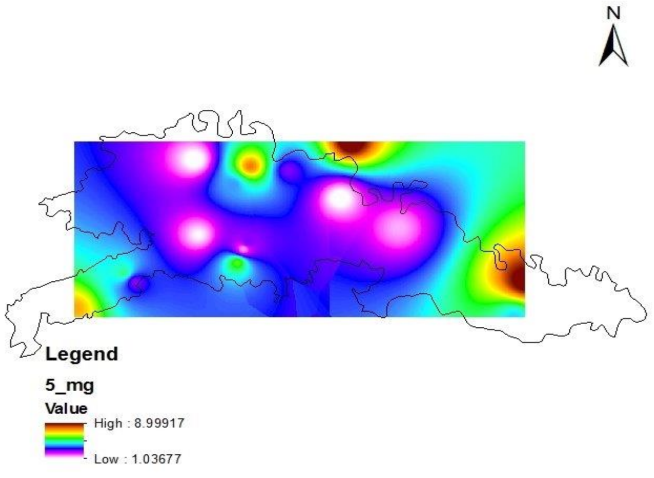

Fig. 12. Spatial Variation of Mg

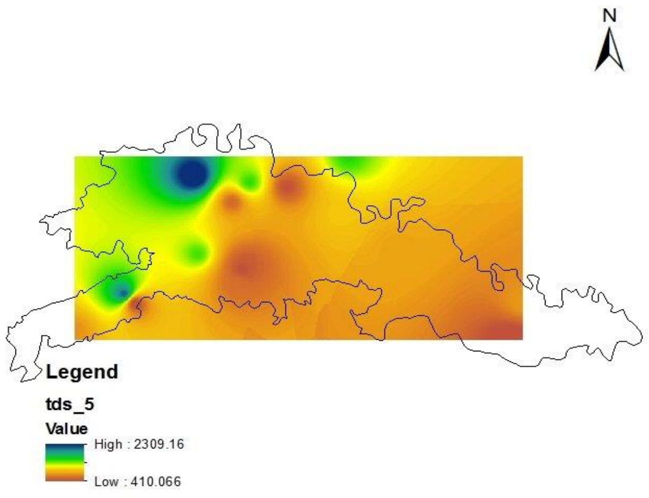

Fig. 13. Spatial Variation of TDS

Spatial interpolation of various physio-chemical parameters explains that the concentration of TDS, Mg, Na, EC are high near the upper Yamuna River where the urbanization is there. The majority of industries are located here. The industrial waste and the domestic waste is dumped either in the open area or in the river. The seepage occurs and hence the contaminants meets the groundwater.

Correlation coefficient and matrix of the parameter is being found out to understand the inter-dependability, and how the concentration of one parameter affects other. Correlation is being calculated and plotted.

Table 1. Correlation Table

	pH	**EC**	**K**	**Chloride**	**Fluoride**	**Bicarbonate**	**Nitrate**	**Sulphate**	**Mg**	**Ca**	**Na**
pH	1										
EC	.002	1									
K	-0.127	0.277	1								
Chloride	.150	**0.935**	0.118	1							
Fluoride	.096	0.424	0.561	0.195041	1						
Bicarbonate	**0.767**	**0.917**	0.552	0.026	**0.786**	1					
Nitrate	0.597	0.211905	0.211	.026	0.302	0.283795	1				

Sulphate	.102	0.35838	0.067	0.182	**0.708**	0.573214	0.05197	1			
Mg	.13	0.511772	0.44	0.478	0.197	0.030238	0.264092	0.166	1		
Ca	-0.107	**.805769**	-0.174	**0.779**	0.112	0.007982	-0.14942	0.276	0.0334	1	
Na	0.041	**0.826**	0.399	**0.727**	0.557	0.476946	0.303619	0.296	0.186	0.452	1

A high positive correlation between electrical conductivity and chloride (0.935), electrical conductivity and calcium (0.805) is observed. Higher concentration of chloride in the water indicates the higher value of electrical conductivity.

The correlation between Fluoride and Bi-carbonate (0.786). Higher value of EC explains the higher salinity in the groundwater.

After incorporating initial conditions, boundary conditions, recharge values, pumping well data. The flow directions comes out to be like this. The average velocity comes out to be 6.8E-5 m/s.

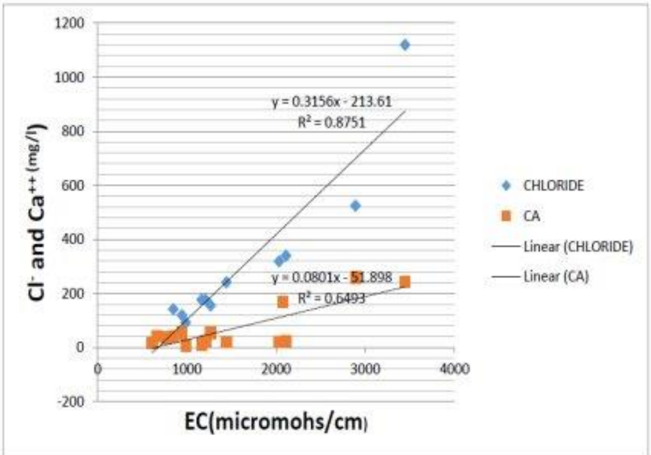

Fig. 14. Correlation between EC and CL- and Ca+

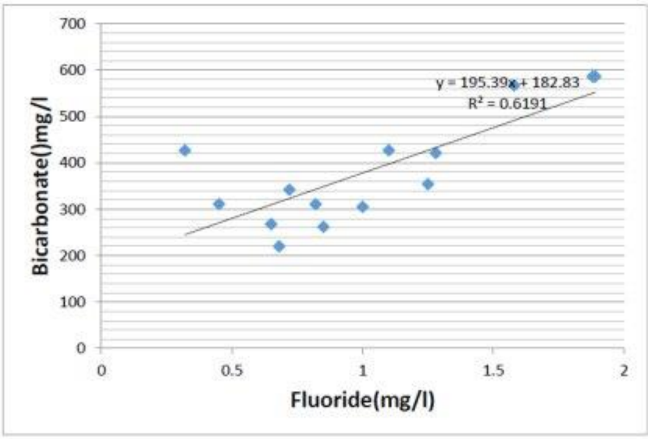

Fig. 15. Correlation between F- and Bi carbonate

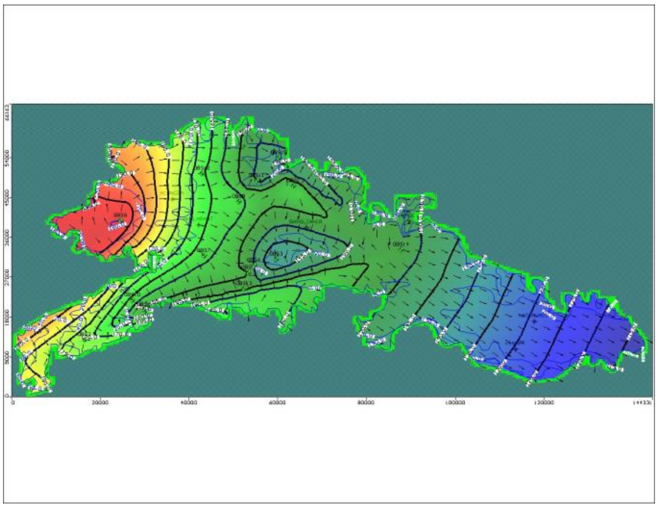

Fig. 16. Velocity Vectors

A close resemblances is been observed between observed and calculated values of the water heads at 1 day time interval from the results obtained from the model.
Correlation comes out to be 0.993 and root mean square error 1.805m
A plot explains it more clearly, the model replicates the same results as it were observed.

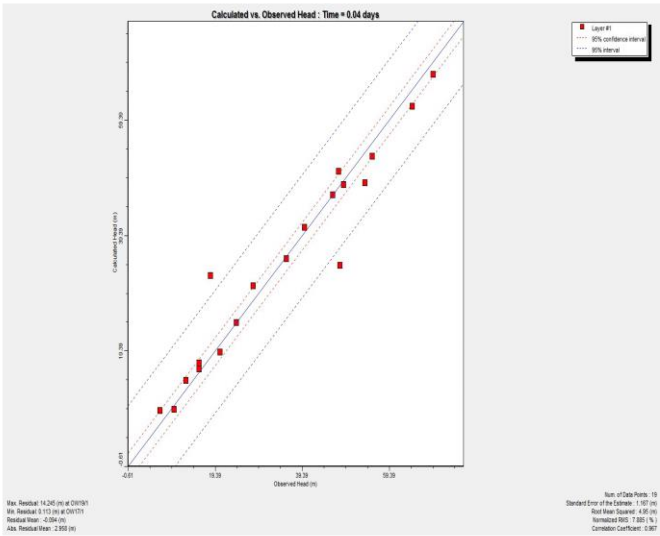

Fig. 17. Calculated Head V/S Observed Head

The MODFLOW results for 1461 days shows correlation coefficient to be 0.814. And root mean squared error was found out to be 17.188m. There is a wide variation between observed and calculated head values.

The head V/s time graph for observation well 6 depicts the accuracy of the results (Figure 18). The observation well values of the head and the model calculated values are almost coming to be equal.

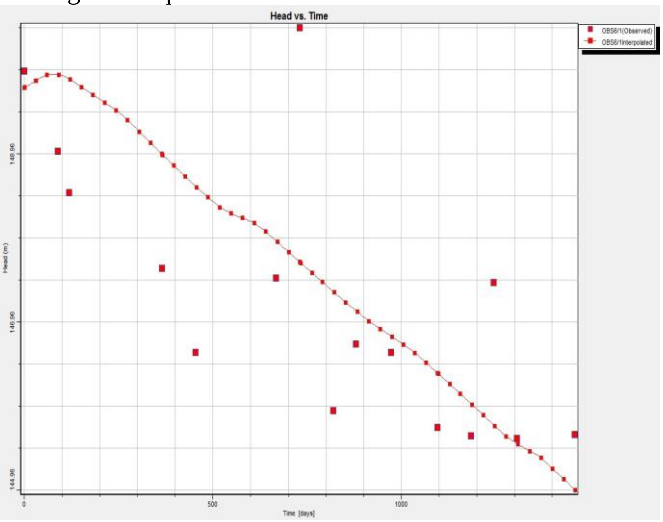

Fig. 18. Head v/s Time @ observation well 6

4. Conclusion

The groundwater quality of the urban region is highly deteriorated mainly due to the industrial setup in that area. The industrial effluents are creating a calamitous effect on the groundwater quality. Effluent discharged from industries involves toxic elements and other heavy metal which affects the groundwater. High correlation was observed between Electrical conductivity and chloride and also between Electrical conductivity and Bi-carbonate. Also higher Electrical conductivity depicts the salinity of the water in that region.

The modelling of groundwater revels the flow directions which is generally north-east to south west, the groundwater flow velocity comes out to be in feasible range with which it flows and also predicts the future scenarios of flow profile so that according to that water management can be done. There is a flow of water towards the centre of the study area as water table is at a deeper depth. The contaminant transport of TDS explains the movement of TDS in groundwater and also predicts the future possible region. The TDS concentration is high in the upper region of the study area. The river conductivity is higher. In the study area, with the increase in time, there is an increase in the depth of water table towards the western region.

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