# GROUNDWATER QUALITY MAPPING AND FORECASTING ALONG VRISHABHAVATHI RIVER STRETCH OF PEENYA INDUSTRIAL AREA BY VISUAL MODFLOW FLEX

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**Abstract -** *The Vrishabhavathi river water was once used by people around Bangalore. Industrial, agricultural and domestic effluents are flowing into the river daily. The Vrishabhavathi watershed carries effluents from various industrial areas viz. peenya, Rajajinagar, Bidadi and kumbalagodu industrial area along with domestic sewage effluents . Vrishabhavathi river that flows along peenya industrial area receives wastewater from near by industries which contains high levels of TDS exceeding the industrial effluent discharge standards, most of the industrial waste ends up flowing into the Vrishabhavathi River thus polluting groundwater. As we cannot see into the subsurface formation, we need a tool that could provide insight into the complex system behaviour this is where groundwater models come into play. Visual MODFLOW flex is one of the groundwater modelling software helps in assessing and forecasting the quality of groundwater. The present study thus aimed at assessing the influence of pollution in the Vrishabhavathi river stretch of peenya industrial area on the quality of groundwater using visual modflow flex. In order to understand the quality of ground water in the study area, TDS was consider as the parameter for the study.*

**Key Words: Vrishabhavathi river, peenya industrial area, industrial effluents, groundwater modelling, visual modflow flex.**

## 1. INTRODUCTION

The River Vrishabhavathi, has got two origins – One originating from the Peenya industrial suburbs and the other from Gavipuram in Guttahalli. Both of the streams join together in Nayandahalli, flows as a single unit from there and joins the River Arkavathi .The length of the river is 52 km and has basin size of about 382 sq km. Many industrial units present along the basin directly discharge their effluents into the river. Only 18% of them are found to possess effective effluent treatment plants. Along the Mysore road there are numerous textile industries, factories manufacturing industrial components and carbonated drinks etc. discharge their untreated waste and effluents directly into the river via their drainage systems. The residents along the bank directly dump all the domestic wastes into the stream. There are also a number of plantations and agricultural fields along the basin where the same toxic water is utilized for irrigation. Now, this is a potential health threat as the plants take up components, which ultimately enters the human body through consumption causing the respective metal poisoning. In this context, present study is under taken to predict the future groundwater quality and to suggest remedial measures of the Vrishabhavathi river stretch along Peenya industrial area.

## 2. OBJECTIVES

- To develop a groundwater flow model for Vrishabhavathi river stretch of peenya industrial area by using visual modflow Flex software with the combination of MODFLOW MODPATH and MT3DMS.
- To study the groundwater Hydraulic head distribution across the study area using MODFLOW.
- To identify the direction and movement of the TDS plume in groundwater using MODPATH package.
- To assess the TDS concentration in the study area Using MT3DMS.
- Predict the future TDS concentration in groundwater of the study area.
- To suggest remedial measures to improve the future groundwater quality of the study area

## 3. LITERATURE REVIEWS

**A. Sushant Kumar et al., (2017),** studied on groundwater resource assessment in Bina river through groundwater modelling. This river water was used for domestic water supply and irrigation supply in Bina river basin. Groundwater modelling in Bina river basin was carried out using visual modflow to understanding the groundwater resources at Bina River basin. The model was run by taking two-layered aquifer. The modelwas calibrated during 2009 pre- monsoon in Bina River Basin. The obtainedmodel results are comparable with the observation data during modelling process.

The modelling results showed that to reduce the groundwater stress it is advisable to redistribute the pumping wells .

B. **R.Rajamanickam et al., (2010),** studied Amaravati river basin which is severely polluted due to discharge of partially treated effluent at the downstream of Karur Town by various dyeing textile and bleaching units. Daily about 14600 $m^3$ of coloured effluent is flowing into the river by various industrial units .Total dissolved solids of 5000-10000 mg/L is discharged into the river daily . using Visual MODFLOW 2.8.1 the study was done , the MODFLOW, and MT3D models were calibrated and validated. The validated model was used for simulation for next 15 years under 5 different scenarios of groundwater quality: (i) if the present system with TDS 10,000 mg/L discharge into river, (ii) if the CETPs discharge the effluent into river with TDS discharge standards of 2100 mg/L and, (iii) if the TDS level is doubled of 2100 mg/L, (iv) if the dyeing units go for reverse osmosis plant to achieve zero discharge and recycle the entire effluent , (v) 1.5 times groundwater recharge and zero discharge by the units. The obtained results showed that even if the effluent met discharge standards for the next 10 years there is no improvement in groundwater quality. there would be an improvement in the quality of groundwater over a period of few years if units opt zero discharge .

## 4. Materials and Methodology

### 4.1 Study Area

**4.1.1 Location details of the study area:** Peenya industrial area is located on the bank of river Vrishabhavathi. The study area taken, is Vrishabhavathi river stretch of Peenya Industrial area of about 6 km length which has area of about 28.40 $Km^2$ ,which is covered in part of the Survey of India Topo Sheet Nos. 57 G/12 and 57 H/8 . This industrial area was established in 1970s. In north-western suburbs of Bangalore the peenya industrial area is located with Latitude 13° 1' 42"N and Long 77° 30' 45"E. Dissected topography can be seen in the Western part of the area where as the eastern part is a level plain. Geologically the area has Achaean era. The major rock types are Gneiss, dyke and granite. The area has gentle slopes and valleys with evenly flat. Predominantly area overlaying by granite and gneiss and red soil is found in the area. The soil is excessively drained and moderately to severely eroded. The drainage pattern is running north-northeast to south-southeast.

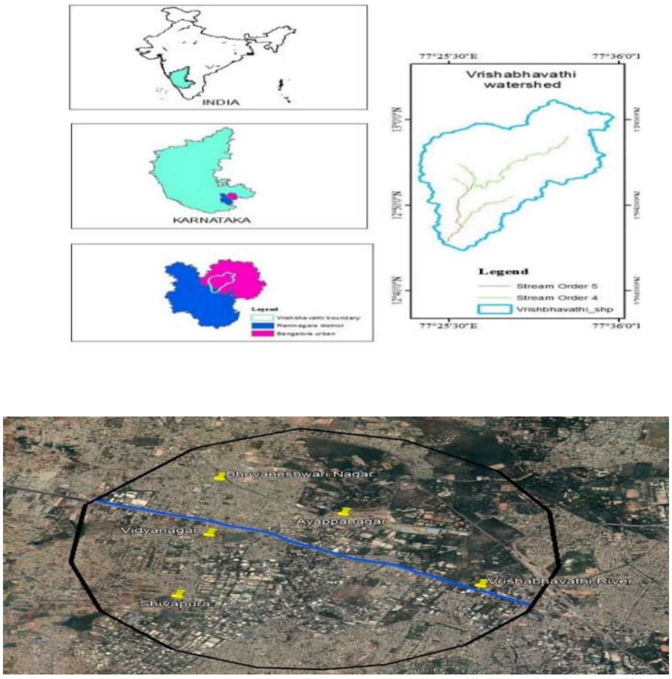


**Figure - 4.1: Location of the study area**

**Figure-4.2 : Polluted water flowing along peenya industrial area**

The major industries in the study area includes textile, bleaching, chemical and dyeing industries. These industrial units are located on either side of Vrishabhavathi river within 3Km from the river .After treatment the effluent is discharged into river Vrishabhavathi, the effluent contains high TDS exceeding the industrial effluent discharge standards this is because all industries doesn't have effluent treatment plants in their premises. the hence for the study TDS is taken as a parameter.

### 4.2 Data collection

Data collection plays an he important role in any modelling process. For this research purpose, data are collected from various departments Viz KSNDMC, literature studies, CGWB reports, Groundwater Year Book, Minor Irrigation Department, Ground water directorate office Bangalore Longitudinal dispersivity of 30 m and transverse dispersivity of 10 m were assumed for the study area. Uniform pumping rate of 100m3/day was assumed for the pumping wells.

## 5. Methodology

Visual MODFLOW (VMOD) Flex is a powerful software package that provides the tools for building three-dimensional groundwater conceptual and numerical models this Modelling software combines MODFLOW which is used to calculate the groundwater distribution in the study area. MODPATH for particle tracking and identifying their movement.MT3DMS provides information about contaminant transport in groundwater flow systems under general hydrogeological conditions. A combination of MODFLOW, MODPATH, and MT3DMS are used to develop a model for the study area. The present study has been carried out using visual modflow flex which is a 3D dimensional groundwater modelling software , to asses the present and future TDS concentration in the study area .

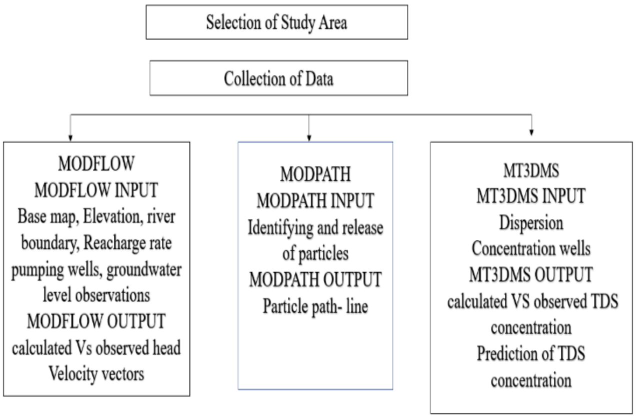


**Figure- 5.1 : Flow chart of modelling process**

## 6. DATA ANALYSIS AND INTERPRETATION

### 6.1 Modflow Model input

**6.1.1 Preparation of Base Map** The base map was clipped using Survey of India Toposheet and georeferenced using ArcGIS. Base map was imported into the model screen in.SHP format.

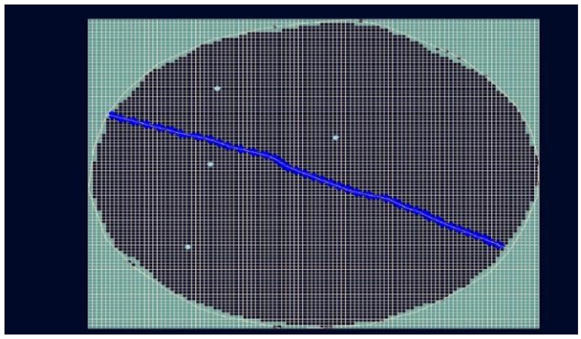

**Figure - 6.1: Model Screen with study boundary, riverboundary and inactive cells**

**6.1.2 Assigning Layer Elevations (Above Mean Sea Level)** : For modeling purpose two layers were considered throughout the study area. The top layer is shallow weathered zone of thickness 30m and the bottom layer is deeper fractured rock with thickness of 230 meters. By using Google Earth Pro, the actual elevation (amsl) of the two layers was entered by importing the text file, which contained the elevation data.

**6.1.3 River Boundary** : The river boundary condition was assigned because the Vrishabhavathi river acts as a source of recharge for the aquifer in the study area. The data regarding Vrishabhavathi river including river stage, river bottom, river bed thickness, conductivity ,river width was assigned with the data collected from Minor Irrigation Department

**Table 6.1 : Vrishabhavathi river Details**

| | | |
|---|---|---|
| **1** | **River stage** | **898m** |
| **2** | **River bottom** | **894m** |
| **3** | **Riverbed thickness** | **2.5m** |
| **4** | **River width** | **16 – 40m** |
| **5** | **Riverbed conductivity** | **1E - 2** |

**6.1.4 Recharge rate:** The recharge package is designed to simulate aerial distributed recharge to the groundwater system .A Reacharge of 65mm/year is assumed for the study.

**6.1.5 Pumping Wells** : four pumping wells are considered in the study area. well screens for the pumping wells were considered from 17 mbgl to 70 mbgl.

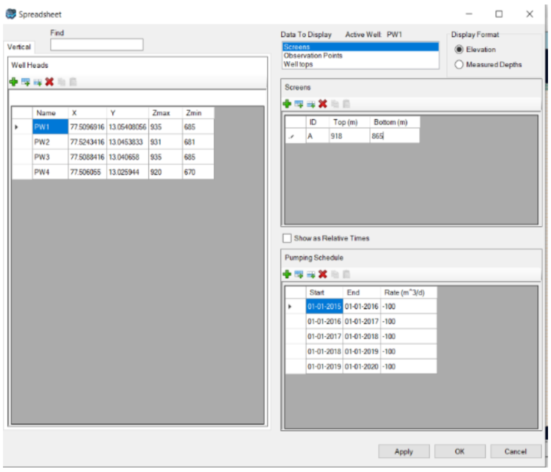

**Figure- 6.2 : Pumping well data assigned into the model.**

### 6.1.6 Assigning Groundwater Level Observations:

Visual MODFLOW flex allows to input data such as groundwater level observations which is shown in below figure

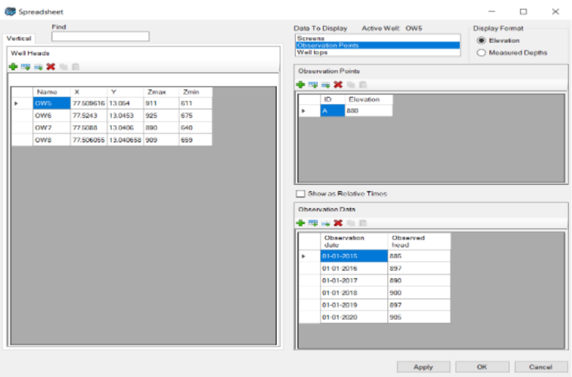

**Figure- 6.3 : Observation well data assigned to model**

### 6.2 MODEL RUN

After completing the input parameters, By selecting [Run] in the Main Menu, Select Run Type dialogue box appears, the modelwas run under transient condition.

### 6.3 MODEL OUTPUT

MODFLOW output provides graphs of calculated vs observed heads, velocity vectors.

### 6.3.1 Transient State Calibration

The transient (dynamic) calibration is carried out for the time period from year 2015 to year 2019 (1520 days). From the graph of calculated head vs. observed it was seen that the calculated values were very closer to the observed value. The graph consists of the continuous blue line indicates 100% correlation between the observed and calculated values.

#### 6.3.1.1 Chart Showing Calculated vs Observed Heads for the year 2015 and 2018

The calibrated chart for the year 2015 showed good match between the observed head in the field versus the model calculated head values. The standard error of estimation was 0.93 m and the root mean squared value was 1.85 m which implies the error of less than 5%. The calibrated chart for the year 2018 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%.

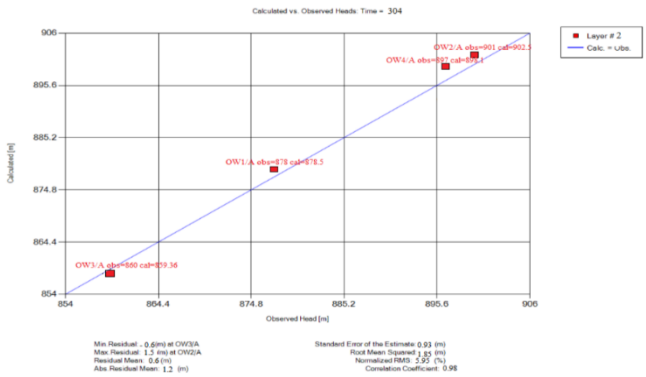


**Figure- 6.4 : Calculated Vs Observed groundwater level (above MSL) for the year 2015.**

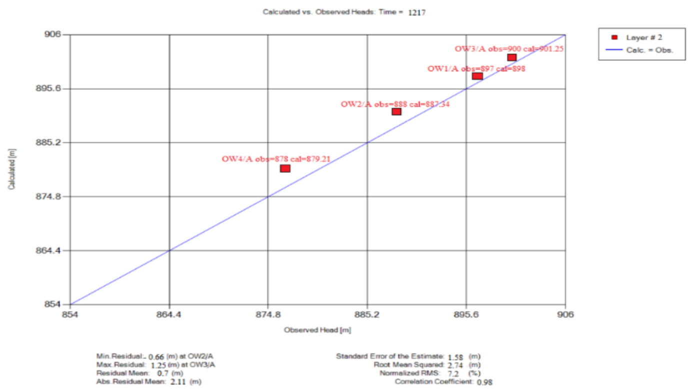


**Figure- 6.5 : Calculated Vs Observed groundwater level (above MSL) for the year 2018**

#### 6.3.1.2 Modflow Model Validation

The model is validated with the year 2020 water level data. The standard error of estimation was 0.88 m and the root mean squared value was 1.55 m which implies the error of less than 5%.

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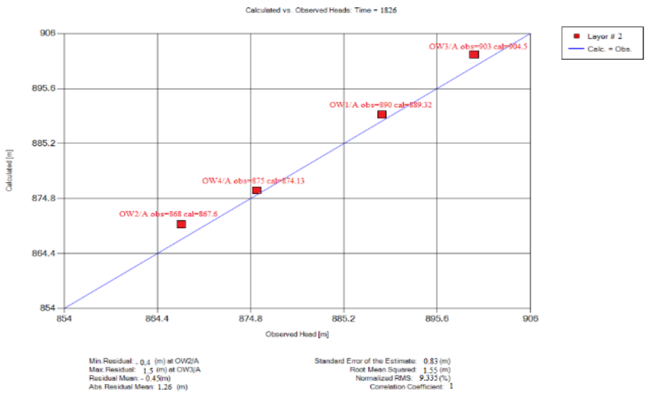


**Figure- 6.6 : Chart showing Calculated vs Observed heads for 1826 days.**

### 6.3.2 Velocity Vectors

Velocity vectors shows the ground water flow is from North-west to West to south east directions following the gravitational flow i.e., from a region of higher elevation to the lower elevation side.

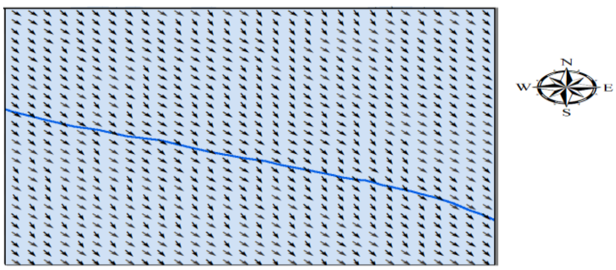


**Figure- 6.7 : Velocity vectors in the study area**

## 7. MODPATH– PATHLINE TRACKING

MODPATH can be used to compute three-dimensional path-lines and the position of particles at specified points in time.

### 7.1Modpath Input

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

### 7.2 Modpath Output

The output from the MODPATH includes the particle path-line direction of the groundwater which was towards the East direction of the study area. movement towards the southeast direction of the river.

## 8. MTEDMS

### 8.1 MT3DMS Input

**8.1.1 Initial Concentration**: The initial concentration of TDS level for the study area was assigned based on 2015 groundwater quality data. The initial TDS concentration is assigned in terms of polygon ranging. By using copy option, the layer-1 properties are copied to layer-2 where ever applicable.

**8.1.2 Dispersion:** longitudinal dispersivity of 30 m and transverse dispersivity of 10 m were uniformly assumed for the entire study area..

**8.1.3 Recharge Concentration :** In the recharge concentration option, TDS concentration that accompanies the flow boundary is specified in the corresponding flow boundary. Due to rapid urbanization and by considering the rise in the TDS concentration, suitable recharge concentrations were assigned to the model.

### 8.1.4 Assigning Groundwater Concentrations

Four concentration wells were in the study area. TDS concentration obtained for the last 6 years (2015-2020). The well screen elevation was given at 45 mbgl for all the four concentration wells. TDS concentration for each specific well was assigned on observation dates

### 8.2 MT3DMS RUN

The MT3DMS was run for a total 3650 days with 1000 transport steps. Upstream Finite Difference method and implicit Generalized Conjugate Gradient (GCG) Solver which is iterative solver was used to solve the mass transport equation.

### 8.3 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.

#### 8.3.1 Chart Showing Calculated vs Observed Concentrations for the year 2015 and 2018

The calibrated chart for the year 2015 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 1.53 mg/L and the root mean squared value was 2.13 mg/L which implies the error of less than 5%. The calibrated chart for the year 2018 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 0.64 mg/L and the root mean squared value was 1.11 mg/L which implies the error of less than 5%.

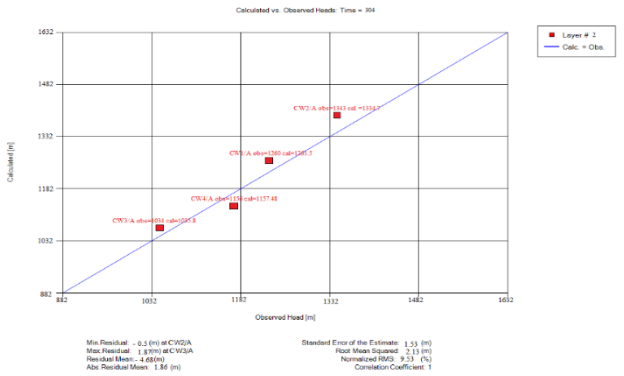


**Figure- 8.2: Calculated Vs Observed Groundwater Concentration (mg/L) for the year 2015**

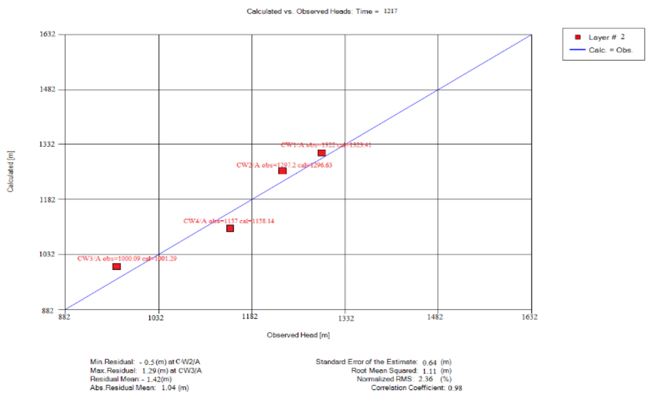


**Figure- 8.3 : Calculated Vs Observed Groundwater Concentration (mg/L) for the year 2018**

### 8.3.3 MT3DMS Validation

After the calibration, the model was validated to data observed in the year 2020 i.e., for the 1826 day. The calibrated chart for the 1826th 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 0.88 mg/L and the root mean squared value was 1.74 mg/L which implies the error of less than 5%.

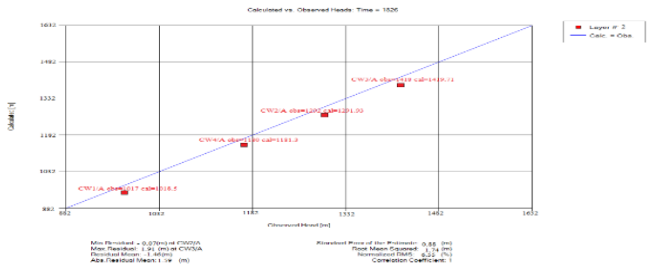


**Figure- 8.4 : chart showing the Calculated Vs Observed Groundwater Concentration (mg/L) for the year 2020.**

## 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. Four wells close to the study area were considered and their impact on the ground water was studied. Four wells are located at Bhuvaneshwari nagar, Ayyappa nagar, Vidyanagar, shivapura

- If the present scenario i.e. river pollution without any control measure continues for next 10 years, what will be the impact on the groundwater quality by the end of year 2029.
- if industries meet TDS discharge of 2100 mg/l and discharge effluents into the river for next 10 years, what will be the impact on the groundwater quality by the end of 2030.
- If improved control measures are taken, such that zero discharge is practiced by the industries for the next 10 years, what will be improvement in thegroundwater quality by the end of year 2029.

The four observation wells located at Bhuvaneshwari nagar, Ayyappa nagar ,Vidyanagar, shivapura for the above three scenarios the forecasting is been present in below figures 9.1,9.2,9.3 and 9.4 respectively.

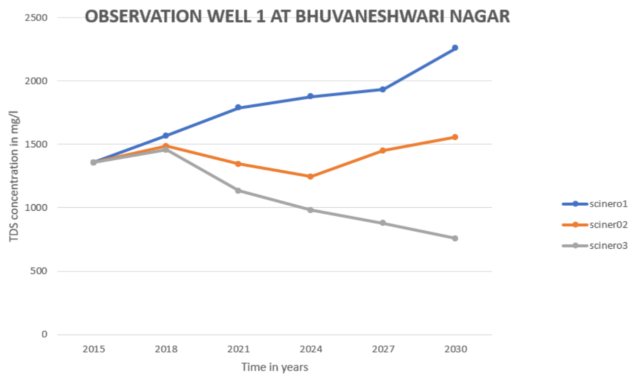


**Figure 9.1 : Forecasted values of TDS concentration in groundwater at Bhuvaneshwari nagar observation well from year 2015 to 2030 for three different assumed scenarios.**

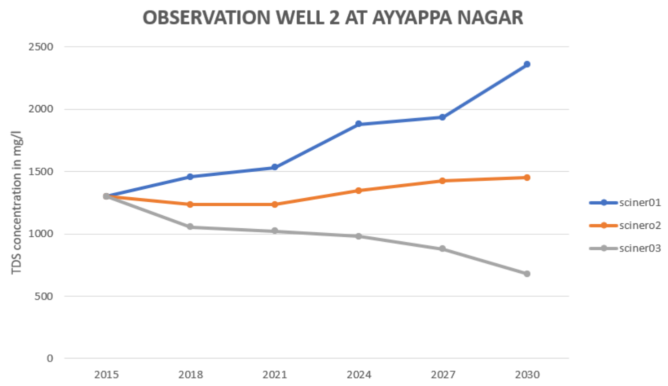


**Figure 9.2 : Forecasted values of TDS concentration in groundwater at Ayyappa nagar observation well from year 2015 to 2030 for three different assumed scenarios.**

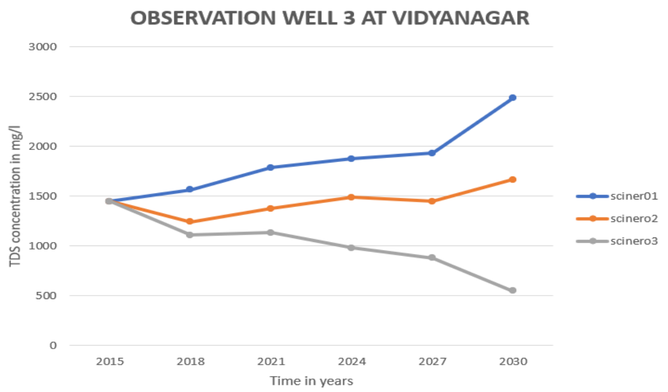


**Figure- 9.3 : Forecasted values of TDS concentration in groundwater at Vidyanagar observation well from year2015 to 2030 for three different assumed scenarios.**

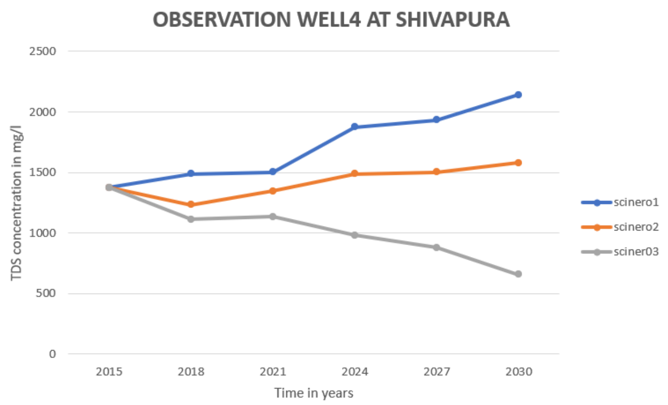


**Figure 9.4 : Forecasted values of TDS concentration in groundwater at observation well shivapura from year 2015 to 2030 for three different assumed scenarios**

## 10. CONCLUSIONS

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

From this study, it comes to understand that Visual MODFLOW flex can effectively be used for studying the pollutant migration in a river basin.The output from MODFLOW, MODPATH and MT3DMS are as follows:

a. 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 four observation wells. From the velocity vectors groundwater direction in the study area can be calculated. The direction of groundwater flow is from the northwest to southeast direction, following the gravitational flow from the higher elevation in the northwest direction towards the lower elevation on southeast direction of study area.

b. The output from the MODPATH derives the particle path-lines that showed the contaminant plume in groundwater moving towards the southeast direction of the study area i.e., impacting the southeast side to a greater extent.

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

1. The prediction for the three scenarios are as follows:
(a) TDS concentration in the groundwater at the end of 2030 under present condition i.e., the scenario 1 shows that, there is increasing trend in the groundwater contamination as the TDS concentrations have reached 2258mg/l, 2357 mg/l, 2487 mg/l, 2140 mg/l at Bhuvaneshwari nagar. Ayyappa nagar, vidya nagar, shivapura concentration well respectively.
(b) TDS concentration in the groundwater at the end of 2030 for Scenario 2 i.e., If industries meet TDS discharge of 2100 mg/l and discharge effluents into the river, shows that there is an increasing trend but below the tolerance limit where the values have reached 1558mg/l, 1450 mg/l , 1667 mg/l, 1578 mg/l at Bhuvaneshwari nagar , Ayyappa nagar, vidya nagar, and shivapura concentration well respectively.
(c) TDS concentration in the groundwater at the

end of 2030 for Scenario 3, If remedial measures such as zero discharge is practiced by industries reducing the TDS concentration shows a declining trend where the values are 756mg/l, 680 mg/l, 550 mg/l, 658mg/l Bhuvaneshwari nagar. Ayyappa nagar, vidya nagar, shivapura concentration well respectively.

2. Results of model simulation for present scenario (scenario 1) depicted that the TDS concentration is increasing this is because industries are letting their pollutants in the river without proper treatment and not meeting the tolerance limits. The TDS concentration in groundwater obtained after 10 years still was not meeting the tolerance imits prescribed for the industrial effluent by the Bureau of Indian Standards for TDS is 2100 mg/l Into inland Surface Waters. Results of model simulation for scenario 2, showed that the TDS concentration in the four concentration wells are below the tolerance limits this is because if industries treat the effluents to tolerance limits prescribed by bureau of Indian standards the pollution of the river can be controlled. By adopting the remedial measures (scenario 3), it was seen that the TDS concentration had been significantly reduced.

3. Remedial measures to improve the groundwater quality of the river are: The industrial area should have a common effluent treatment plant (CETP) to process the liquid/solid effluent generated from different industries and no liquid waste disposal may be allowed within the industrial area as in situ infiltration rates of top granitic is high.

## 11. REFERENCES

[1] Rajamanickam (2011)modeling using visual modflow of Amaravati river basin of karur district.
[2] Sushant Kumar M. K. Choudhary T. R. Nayak ( 2017 ) ,Groundwater Modelling in Bina River Basin, India using Visual Modflow IJSRD - International Journal for Scientific Research & Development
[3] Waterloo Hydrogeologic Inc. (2019) a visual modflow flex 6.1 Integrated Conceptual & Numerical Groundwater Modeling Software User's Manual", www.waterloohydrogeologic.com © 2019 by Waterloo Hydrogeologic . . Published: July 2019 in Waterloo, Canada
[4] Karnataka State Pollution Control Board (KSPCB) Bangalore, Karnataka (2018), Assessment of groundwater conditions and water quality around Peenya Industrial Development Area.
[5] B. S. Shankar & N. Balasubramanya & M. T. Maruthesha Redd( 2008) a case study of Peenya industrial area, Bangalore. Impact of industrialization on groundwater quality
[6] Dr. Prasanna Kumar S.C ( 2019) Real-Time Water Quality Monitoring system for Vrishabhavathi River of Bengaluru
[7] Priyanka Jamwal and Sharachchandra (2017) Lessons from the Vrishabhavathi river in Bengaluru Addressing pollution in urban rivers
[8] Ramachandra T.V Vinay S Rejuvenation Blueprint for Vrishabhavathi valley
[9] Raja kumara H N, Ganesh Raj K, Ramesh K S, Vidya A, Ajay Kumar V (2019)Rainfall Analysis of Vrishabhavathi Valley in Bengaluru Region
[10] Vijay Chellaram ( 2017) Vrishabhavathi Valley Wastewater Treatment Plant System Upgrade