GROUND WATER MODELLING FOR RAIN WATER HARVESTING SYSTEM

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ABSTRACT

Groundwater is the largest reservoir of fresh water on the planet earth. In many areas of developing countries, increasing groundwater use has led to depleted aquifers. Artificial groundwater recharge using rain water is a basic concept for the sustainable management of vital freshwater resources. This study aimed to develop a methodology to assess the impact of RWH for an urban aquifer. A groundwater model is developed for simulating the effect of RWH and to predict the future scenario. The period of Jan 1995 to December 2000 is used for model calibration process and the period of Jan 2001 to January 2003 is used for validation process. The model is simulated in transient condition for a time interval of 9 years from January 2004 to May 2012. The calibrated model (pre RWH period that is influenced by natural recharge only) is used to simulate the regional groundwater head and it is compared with the observed data (that is influenced by both natural and artificial recharges (due to RWH implementation in the year 2003)) of 15 wells. The difference of observed head and simulated head indicates the impact of RWH. Prediction scenario on the effect of artificial recharge is carried out from 2012 to 2025. There is a difference of 2 m water table in each scenario for 20% increase or decrease in pumping and recharge rate. The impact of RWH simulated through modeling shows the improvement of water table. But, the results from the future prediction scenarios indicate that water table will go down if pumping is increased and rainfall is decreased. Hence, there is a necessity to educate the society for proper usage of ground water and maintaining the RWH structures.

***Keywords** : Artificial Recharge, Rainwater Harvesting, MODFLOW, GIS*

INTRODUCTION

Water is the basic necessity of life. In the recent decades, many countries are facing serious issues of water quantity and quality. The global community acknowledges a water crisis: the UN has declared 2005-2015 as the decade of water (Glendenning 2009). More than 2000 million people would live under conditions of high water stress by the year 2050. Groundwater is the largest reservoir of fresh water on the planet earth and is intensively exploited in many urban centers of the developing world. Natural replenishment of groundwater reservoir is a slow process and is often unable to keep pace with the excessive and continued exploitation of groundwater resources in urban areas. This results in declining groundwater levels & depletion of groundwater resources, leading to several vexing problems like reduced well yields, land subsidence and intrusion of salty water, especially in coastal areas. In order to over-come these serious environmental implications and to improve the groundwater situation, it is necessary to artificially recharge the depleted groundwater aquifers.

The source of water for artificial recharge could be rainwater (collected during and just after rainfall), surface water (in the form of river, lakes, reservoir, percolation pond, etc) and / or groundwater (taken out from a place of abundant availability to a place of water shortage). Of these, rainfall is the source for surface and groundwater. The rainfall occurrence in any tropical country is not evenly distributed and limited to a few monsoon months. In India, rainfall occurs only in 100 hours (1.14%) out of 8760 hours in a year (Sivanappan 2006). This warrants saving of water during rainfall for use in lean periods. In the recent times, artificial recharge techniques using rain water known as “Rain Water Harvesting” are practiced in many tropical countries.

In urban areas, rain water available from roof tops of buildings, paved and unpaved areas can be collected and stored (either recharged to aquifer or stored in underground sumps) that can be utilized gainfully at the time of need. Such structures can be adopted widespreadly by any society for effective conservation. A few techniques of roof top rain water harvesting in urban areas are recharge pit (with similar dimensions of length, breadth and depth), recharge trench (similar dimensions of breadth and depth but larger lengths), recharge shaft (smaller diameter and larger depth) and recharge well (larger diameter and larger depth). Existing dug wells and tube wells can also be used as RWH structures with filtration of rain water to avoid surface impurities from entering the well.

RWH is practiced mostly for recharge purposes in urban areas through various techniques resulting in improved groundwater potential. Consequently, it converges to estimation of incremental recharge due to implemented RWH structures, which could be estimated as increase in water levels of the wells as well as increase in net recharge (as the height of water in different strata implies different yields). Modeling of groundwater movement in the region will help in understanding the aquifer behavior leading to assessment of RWH impact and prediction of future courses.

Jaworska-Szulc (2009) carried out the groundwater flow modeling of multi-aquifer systems for regional resources evaluation of the Gdansk hydro geological system of Poland. MODFLOW was used to develop a three-dimensional steady state model on the basis of data from over 1,700 boreholes. Chenini and Mammou (2010) carried out the groundwater recharge study in an arid region using GIS techniques and numerical modeling in Maknassy basin, which is located in Central Tunisia. Martínez-Santos et al (2010) modeled the effects of groundwater based on urban supply in low permeability aquifer of Madrid in Spain. Senthilkumar and Elango (2011) modeled the impact of a subsurface barrier on groundwater flow in the lower Palar River basin of Southern India. Taheri and Zare (2011) carried out groundwater recharge modeling of Kangavar Basin, a semi-arid region in the western part of Iran using MODFLOW. Groundwater modeling is widely used as a management tool to understand the behaviour of aquifer systems under different hydrological stresses, whether induced naturally or by human activities. From the various literatures, it is clearly known that, with the help of models and with various prediction scenarios, management policy can be framed for the future protection/ management of aquifer.

STUDY AREA DETAILS

Chennai, the capital of Tamil Nadu State and the oldest of the presidential cities in India is selected as the study area. The index map of study area with the specific region chosen for the study is presented as Figure 1. Chennai is located at 13.04° N and 80.17° E on the southeast coast of India occupying a total area of 174 Sq. km and is on a flat coastal plain at an average elevation of 6 m. Two rivers meander through Chennai, the Cooum River in the central region and the Adyar River in the southern region. The Buckingham Canal, 4 km inland, travels parallel to the coast, linking the two rivers. The average annual rainfall is about 1,300 mm. The city gets most of its seasonal rainfall from the north-east monsoon winds, from mid-September to mid-December. The geology of Chennai comprises mostly clay, shale and sandstone. Historically, Chennai has faced problem of water shortages as no big river flows through it, resulting in over-reliance on annual monsoon rains to replenish reservoirs. The city's ground water levels were depleted to very low levels in many areas. In recent years, due to heavy and consistent monsoon rains and the implementation of rainwater harvesting (RWH) techniques, water shortages have been reduced significantly and this has led Chennai to be a model of RWH technology for other cities.

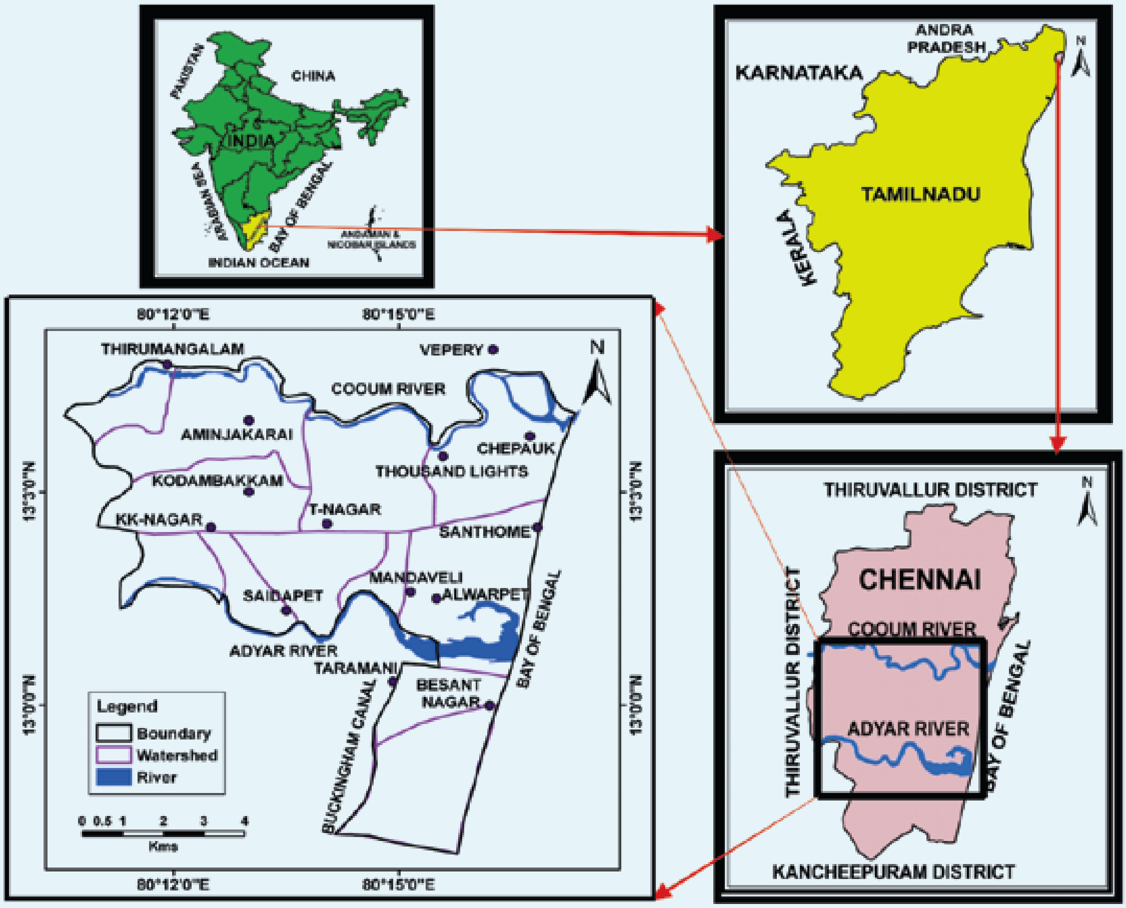


Fig. 1 : Index Map of Study Area

METHODOLOGY

Visual MODFLOW software is used to build a groundwater flow model and to simulate the behavior of flow systems under different stresses such as groundwater recharge rates and pumping based on projected demands. Importance is given to predict the groundwater flow and groundwater head temporally and spatially and to investigate the effect of groundwater abstraction and recharge at a well on the flow regime and predicting the resulting change in groundwater levels with different management scenarios.

Base map of the study area is created in Arc GIS software and the same is imported to the visual MODFLOW. The study area is divided into grids of size 100 m x 100 m. The boundary conditions such as flow boundary, no flow boundary; active and inactive cells are fixed. The elevation data set of the study area is entered. The number of layers of aquifer along with its thickness is also finalized. Observation wells and pumping wells are located along with their thickness of screen and maximum depth of well. Aquifer properties such as hydraulic conductivity, porosity, specific yield, transmissivity and river stages are entered as input data. Rainfall recharge, pumping rate and evapotranspiration for the total study area is estimated and given as input.

Model parameters are estimated through a trial and error process until a good match between computed and observed water heads is obtained. Statistical analysis of the calibration results in steady state and transient state are carried out. Then the model is validated by comparing the results of the model with the observed data. The calibrated model (for the pre-RWH period, influenced by natural recharge only) is used to simulate the regional groundwater head and it is compared with the observed head (that is influenced by natural and artificial recharge (due to RWH implementation in the year 2003)). The difference of observed head and simulated head indicates the impact of RWH, if any. The model is also used for the prediction of future hydrogeological conditions of the study aquifer, according to three various scenarios of pumping and recharge.

ANALYSIS AND RESULTS

Model Formulation and Development

The conceptual model of the hydro-geologic system is derived from a detailed study of the geology, borehole lithology and water level fluctuations in wells. Groundwater in the study area is found to occur both in alluvial formations and underlying weathered rocks. Hence, the top unconfined alluvium is considered. In order to consider the variations in lithologic and hydraulic characteristic with depth, two layers are considered. The top layer constitutes the alluvial floodplains of the river, which is predominantly of fine sand. The second layer has sand to sedimentary formation. The thickness of each layer varies from 5 to 15 m.

MODEL INPUT DATA AND BOUNDARY CONDITIONS

Importing Base Map and Refining of Model Area

The base map collected from Survey of India is digitized in three themes viz., boundary, river and well locations using Arc GIS and imported to the Visual MODFLOW. The model area is divided into cells containing 130 columns and 140 rows. The size of each grid cell is 100 m x 100 m.The cells located out of the study area are designated as inactive cells and the cells within the boundary are considered as active cells.

Importing Elevation Data to All the Layers

GPS survey is conducted in the study area and the elevation database is created for all the 53 primary well locations and 15 observation well locations. The elevations of each layer are created in ASCII format. These files are imported into the Visual MODFLOW to create the two layer aquifer system as shown in Figure 2. The surface elevation, bottom of the upper aquifer, bottom of the lower aquifer , in meters, with respect to mean sea level ranges between 5 and 16 ; -4 and 7 & 2 and -18 respectively.

Importing Data for Pumping Wells and Observation Wells

There are 28 representative pumping wells in the study area. The total demand (pumping quantity) of the study area is assumed to be met by these 28 representative pumping wells. The monthly pumping quantity of these representative wells are given as the input. It is imported into the model by using the "ADD WELL" option in MODFLOW along with the details of the wells namely well identification details, coordinates of the well, screen depth and pumping rate. Similarly, there are 15 observation wells which are monitored by the various government agencies (PWD and CGWB) and the details of the observation wells are also

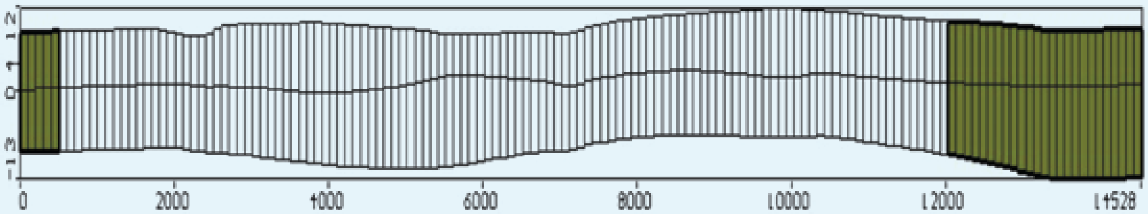


Fig. 2 : Lithology formation map

added. Monthly rates of groundwater withdrawal are applied for every stress period during the simulation. The locations of observation and pumping wells are shown in Figure 3.

Importing Aquifer Properties to the Model

Hydrogeological properties are the major governing factors in defining the physical framework of an aquifer and to control the movement and storage of groundwater. The aquifer parameters such as hydraulic conductivity, specific yield and storage coefficient are taken from pumping tests data, collected from CGWB and also through literature survey. Based on the lithology, the study area is divided into three zones and aquifer properties such as hydraulic conductivity, porosity and specific yield are assigned. After various trials of run, the distribution of hydraulic conductivity for each layer of the regional groundwater model in the layers 1 and 2 is finalized. The aquifer is assumed to be horizontal by isotropic ($k_x = k_y$) and to have a vertical conductivity of 0.1 times of k_x, where k_x is hydraulic conductivity in the X-direction of the model, k_y hydraulic conductivity in the Y-direction and K_z is hydraulic conductivity in the Z-direction. In layer 1, it ranges between 65 m/d and 40 m/d from east to west. The low K value along the west side of the boundary is attributed to the presence of sandy clay and clay. In layer 2, it ranges between 55 m/d and 15 m/d. The specific yield of the study area ranges from 0. 015 to 0.1

Assigning Boundary Conditions

Three boundary conditions are assigned for the study area based on the interpretation made using borehole lithology and physiography. The Western and Southern side of the basin is considered as no flow boundary. River courses of Adyar, Cooum and Buckingham canal are given river head boundary. The rivers flow only during rainy seasons. The Bay of Bengal on the East, is taken as constant head boundary.

Estimation of Model Input Parameters

The recharge to the aquifer varies spatially due to the differences in soil type, land use and topography. It also varies depending on the amount of rainfall. Based on the geology, the study area is classified in to three zones of recharge. Before implementing RWH structures, there is only natural recharge. But after implementing RWH structures, the recharge is due to natural recharge and artificial recharge. The rainfall recharge ratio is calculated using the recharge estimated from water level fluctuation method. Before implementing the RWH structures, this ratio is less and got increased after the provision of the same. Before RWH period, the rainfall recharge rates are 19% to 27% in Zone A since it is a coastal sandy aquifer, 15 to 25% in Zone B since the top layer is sandy clay and 13

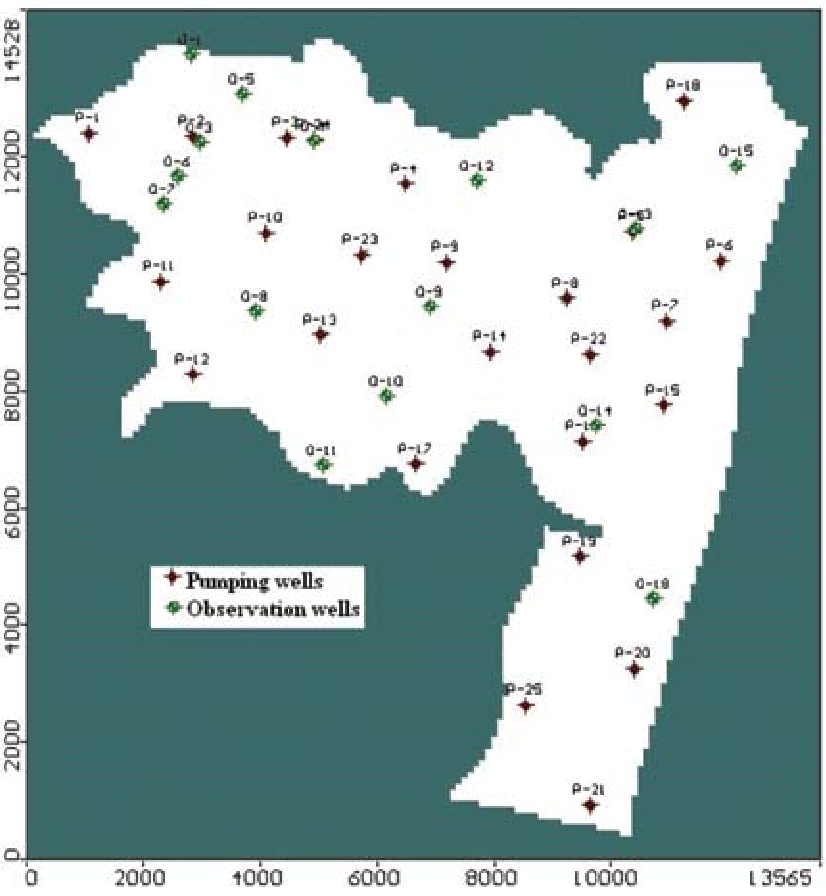


Fig. 3 : Locations of pumping and observation wells

to 23% in Zone C since the top layer is silty clay. But after RWH period, the rainfall recharge rate is increased further to 12% . 8% and 6% in Zones A, B and C respectively.

The groundwater of the study area is abstracted only for domestic purposes. Well inventory data is collected from CGWB and Department of Economics and Statistics. The pumping rate of wells that exist within the study area is taken into account and pumping rates from these wells are estimated by collecting data on quantity of water pumped and pumping duration in a day through field visits. From the questionnaire survey and water survey data collected from Shri AMM Murugappa Chettiar Research Centre, Taramani, it is realized that the average amount of pumping in a day is 500 litres from each well/house. This is verified with the data collected through a questionnaire survey (primary data collection as part of this thesis) by considering the population and a maximum pumping of 50 lpcd. During monsoon period, water supply from CMWSSB is more and hence pumping is reduced to 30 lpcd. Hence, variable pumping is assumed from monsoon to summer period.

In order to estimate the evapotranspiration values, minimum and maximum temperature values are collected from IMD and Department of Economic and Statistics. Reference evapotranspiration is estimated using the following equation (1) stated by Hargreaves and Samani (1982).

$$E = 0.0023\,(T\ mean + 17.8)\,(T\ max - T\ min)^{0.5}\ Ra \qquad ...(1)$$

Where T mean - Mean temperature
T max - Maximum temperature
T min - Minimum temperature
Ra - Net radiation.

Using the above equation, evapotranspiration values are calculated for the study period and fed into the model to simulate the effects of plant transpiration, direct evaporation and seepage at the ground surface by removing water from the saturated ground water regime.

MODEL CALIBRATION

Before a groundwater model is used for any predictions or decision-support, it should be calibrated in order to show that it simulates the groundwater behaviour satisfactorily. Model calibration consists of modifying the model input parameters to match with the field conditions. This requires that field conditions at a site be properly characterized. Input parameters and boundary conditions are varied until the model results agree with the field observations within a pre-established range of error. In MODFLOW, boundary conditions, recharge and hydraulic conductivity are the major parameters that are predominantly modified in order to obtain a reasonable fit with observed values of hydraulic head and flow rate at outlet streams. The model is calibrated in two stages, which involved a steady state condition and a transient state condition.

Steady State Calibration

Steady state calibration is done for the period January 1995. The steady state model calibration is started by minimizing the differences between the computed to the field water level data for the observation wells by adjusting the various aquifer parameters. Steady state calibration statistics are summarized in Table 1. A number of trial runs are made by varying the hydraulic conductivity values of the upper and lower layers so as to get the better match between the observed and computed heads. Figure 4 shows the comparison between calculated and observed hydraulic heads in steady state calibration.

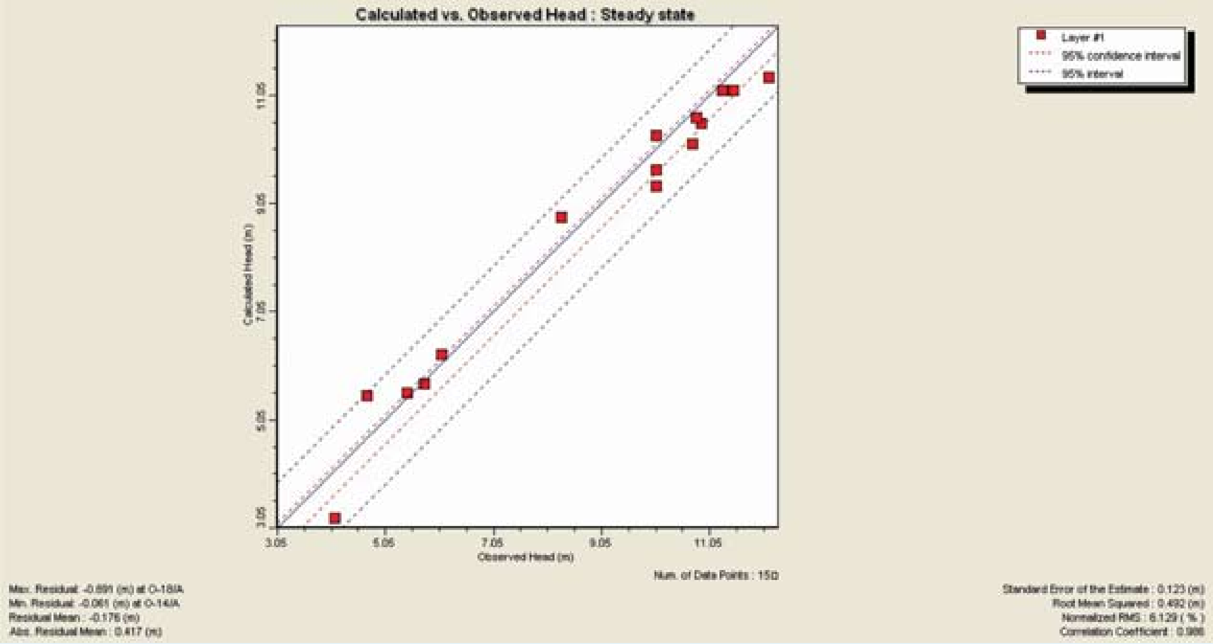


Fig. 4 : Comparison between Calculated and Observed Hydraulic Heads

Table 1 : Summary of Steady State Calibration Statistics

Sl. No.	Parameter	Values
1	Number of observation wells	15
2	Maximum residual at well no.18	- 0.891m
3	Standard error of the estimate	0.123 m
4	Minimum residual at well no.14	- 0.061m
5	Root mean square	0.492 m
6	Residual Mean	- 0.176 m
7	Normalized RMS	6.129%
8	Absolute Residual Mean	0.417m
9	Correlation coefficient	0.986

The calculated steady state water level contours in the first layer is shown in Figure 5. The groundwater flow direction is towards the coast and the rivers. In coastal watershed, water table elevation varies from 0 to 4 m, dense urban watershed 6 to 10 m but in sub urban watershed, it varies from 8 to 14 m.

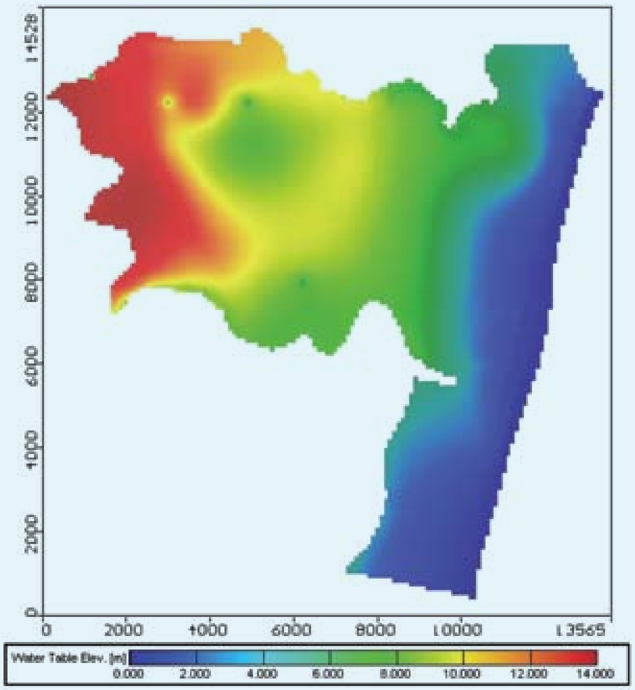


Fig. 5 : Computed steady state water level contours in top layer

Transient Calibration

The piezometric surface calculated from the steady state simulation is established as initial conditions for the transient flow simulation. The hydraulic conductivity values, boundary conditions and water levels arrived through the steady state model calibration is then used as the initial condition in the calibration of transient flow model. The transient calibration is carried out for the time period of Jan 1995 to Dec 2000. The calibration strategy is to initially vary the best known parameters as little as possible and vary the poorly known or unknown values the most, to achieve the best overall agreement between calculated and observed datasets.

Out of all the input parameters, the hydraulic conductivity and specific yield are the poorly known. Based on the data, it is decided to vary hydraulic conductivity and specific yield values upto 10% to get a good match of the calculated and observed heads. The root mean square error and the mean error are minimized through numerous trial runs. Transient state calibration results and statistics are summarized in Table 2. Figure 6 shows the comparison between computed and observed hydraulic heads in transient model calibration at a time step of 1590 days.

Table 2 : Summary of transient state calibration statistics

Sl. No.	Parameter	Values
1	Number of observation wells	15
2	Maximum residual at well no.18	- 1.064m
3	Standard error of the estimate	0.166 m
4	Minimum residual at well no.14	- 0.002m
5	Root mean square	0.627 m
6	Residual Mean	- 0.183 m
7	Normalized RMS	6.895%
8	Absolute Residual Mean	0.545m
9	Correlation coefficient	0.986

Groundwater hydrograph for all observation wells for observed and calculated heads are checked and found to be matching. Figure 7 shows the sample groundwater hydrograph for observation well located in suburban watershed.

Spatial analysis of computed water levels is also carried out in Modflow for all periods and computed water level contours at a time step of 1830 days in Jan 2000 is shown in Figure 8, which indicates that water table elevation of the study area vary from 0 to 12 m from east to west. From January 1995 to Jan 2000, there is a difference of 2 m in water table elevation, indicating that water level had gone down by 2 m.

MODEL VALIDATION

Model calibration process in general does not provide any uniqueness in arriving at a realistic value of a particular parameter. Because of this uncertainty, calibrated parameters need not represent the field situation and the predictive capability of such models is questionable one. It is therefore strongly recommended to have model validation in order to have greater confidence on the calibrated model. In this study, the period of January 1995 to December 2000 is used as model calibration process and the period of Jan

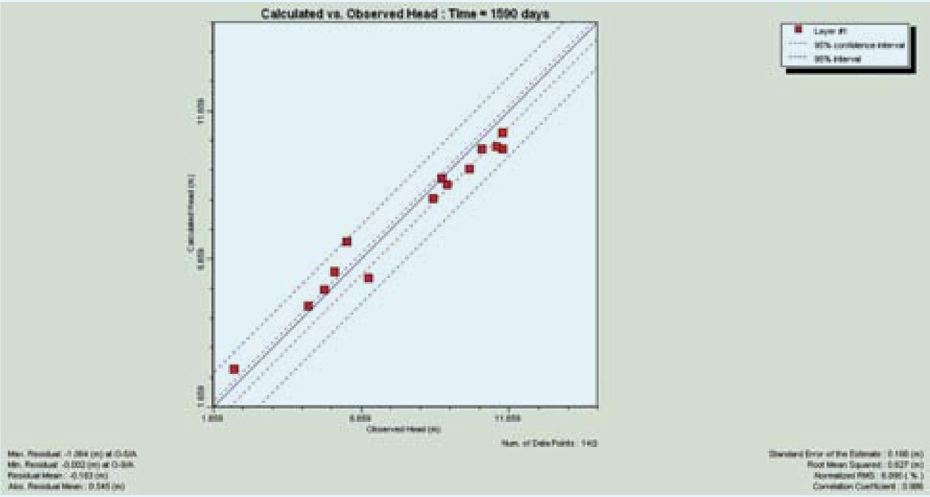


Fig. 6 : Comparison between calculated and observed hydraulic heads at 1590 days

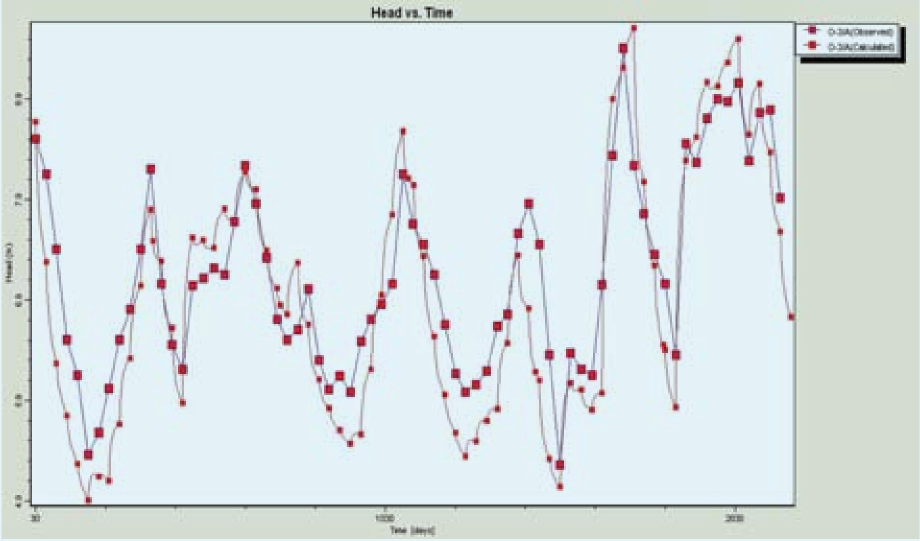


Fig. 7 : GW hydrograph of observation well (suburban watershed)

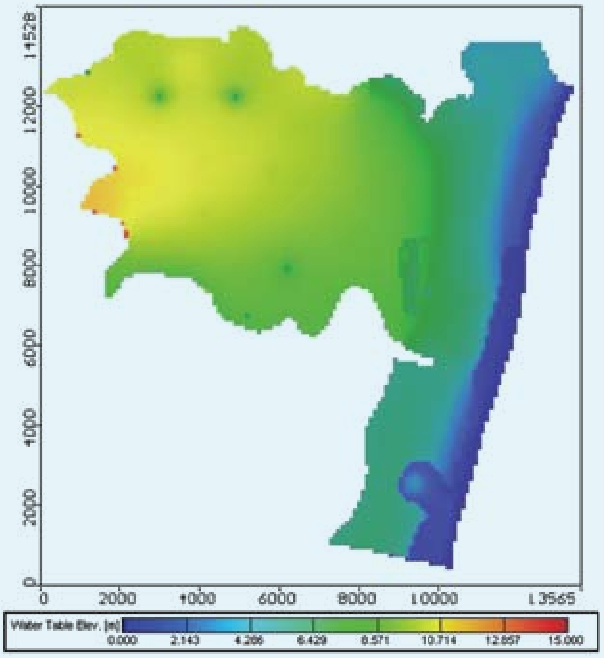


Fig. 8 : Computed water level contours for January 2000

2001 to January 2003 is used as model validation process. After the model calibration, the field values are made available to compare and it is found that a good match exists between the computed and observed values. Figure 9 shows the comparison between computed and observed hydraulic heads at a time step of 2520 days. Groundwater hydrographs for computed and observed hydraulic heads are compared for all observation wells and the sample graph of a well located in dense urban water shed is shown in Figure 10.

Spatial analysis of computed water level is also carried out in Modflow for all periods and computed water level contours at a time step of 2910 days (January 2003) is shown in Figure 11, which indicates that water table elevation of the study area varies from 0 to 10 m from east to west.

From January 1995 to January 2003, there is a difference of 4m in water table elevation indicating that the water level had gone down by 4 m. Therefore, the importance of artificial recharge by RWH is thought of by the Tamilnadu Government and made mandatory which facilitates the improvement of groundwater table.

MODEL SIMULATION FOR IMPACT OF RWH

The model is simulated in transient condition for a time interval of 9 years from January 2004 to May 2012. The

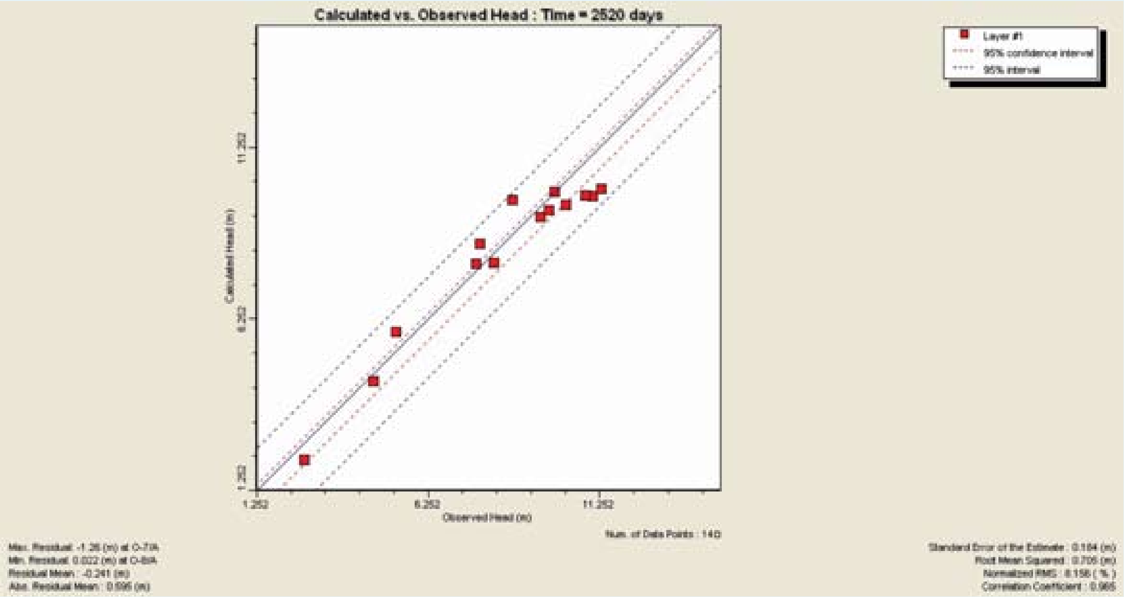


Fig. 9 : Comparison between computed and observed hydraulic heads at 2520 days

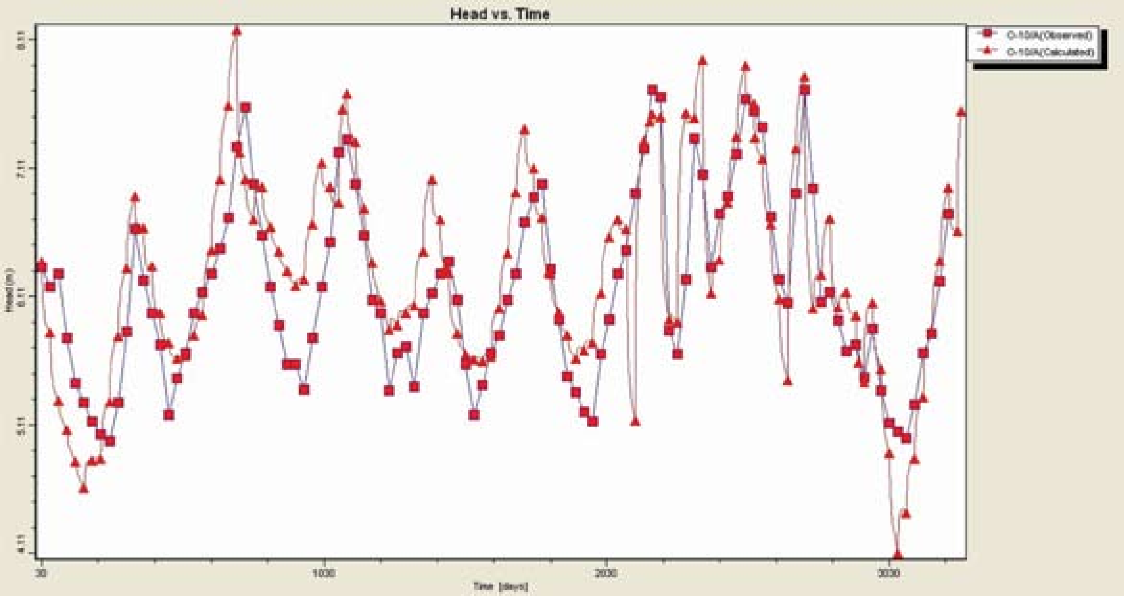


Fig. 10 : GW hydrograph of observation well (dense urban watershed)

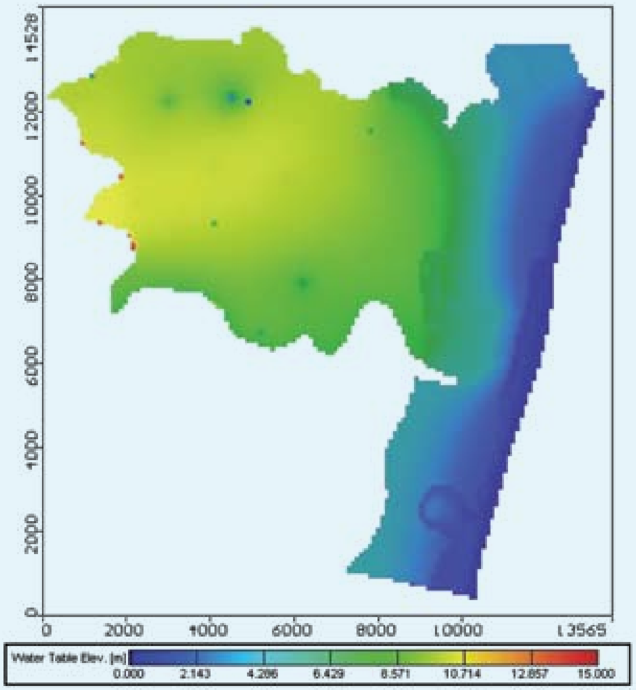


Fig. 11 : Computed Water Level Contours for Jan 2003

calibrated model (pre RWH period that is influenced by natural recharge only) is used to simulate the regional groundwater head and it is compared with the observed data (that is influenced by natural and artificial recharge (due to RWH implementation in the year 2003)) of 15 wells. The difference of observed head and simulated head indicates the impact of RWH, if any.

The results of impact analysis for Jan 2004 are presented in Table 3, where the rise of water table is noticed in 10 observation wells and fall in 5 wells. Observation well nos 1, 3, 7 and 12 are located in sub urban watershed indicates that RWH structures provided are not sufficient to improve water table. This point is already reflected in the results of investigation of RWH structures, explained in the previous chapter. But, well no. 14 shows the improvement in 2005. Overall, the average rise of water table in January 2004 is estimated to be 0.736 m for the monsoonal rainfall of 0.68 m.

Similarly, analysis is carried for all periods and Table 4 indicates impact of RWH from 2004-2012. A graph shown in Figure 12 represents the trend of impact of RWH. In the beginning, the ratio of water table rise to monsoon rainfall is more but is having a decreasing trend. This is mainly because of the fact that the implemented RWH structures are losing their efficiency to recharge over a period of time. The top layer of RWH structures would have got choked with debris and impurities and are to be removed and replaced at regular intervals. There is a necessity to rejuvenate the RWH structures through regular maintenance for its possible continued impact on the groundwater sustainability.

Table 3 : Impact of RWH in January 2004

Sl. No.	Observation well No.	Observed water table (msl)	Calibrated water table (msl)	Rise/fall (m)
1	5	10.24	8.79	1.45
2	6	12.48	9.67	2.81
3	8	11.03	9.66	1.37
4	9	10.48	8.50	1.98
5	11	7.29	7.27	0.02
6	13	6.69	3.65	3.04
7	15	5.88	2.53	3.35
8	18	3.96	1.52	2.44
9	1	8.43	9.45	-1.03
10	3	6.75	7.24	-0.49
11	4	8.76	8.61	0.15
12	7	8.55	9.97	-1.42
13	10	7.06	6.62	0.44
14	12	5.77	8.50	-2.73
15	14	4.32	4.72	-0.40

Table 4 : Impact of RWH from 2004 to 2012

Sl. No.	Month/ year	Average rise of water table (m)	Monsoon rainfall (m)	Water table/ rainfall ratio
1	Jan-04	0.73	0.68	1.0735
2	Jan-05	0.84	0.91	0.9231
3	Jan-06	1.8	1.94	0.9278
4	Jan-07	1.42	1.29	1.1008
5	Jan-08	1.2	1.15	1.0435
6	Jan-09	1.05	1.16	0.9052
7	Jan-10	0.99	1.14	0.8684
8	Jan-11	1.27	1.42	0.8944
9	Jan-12	1.02	1.19	0.8571

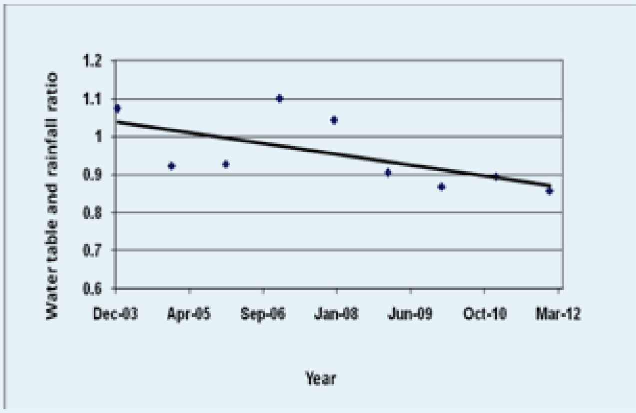
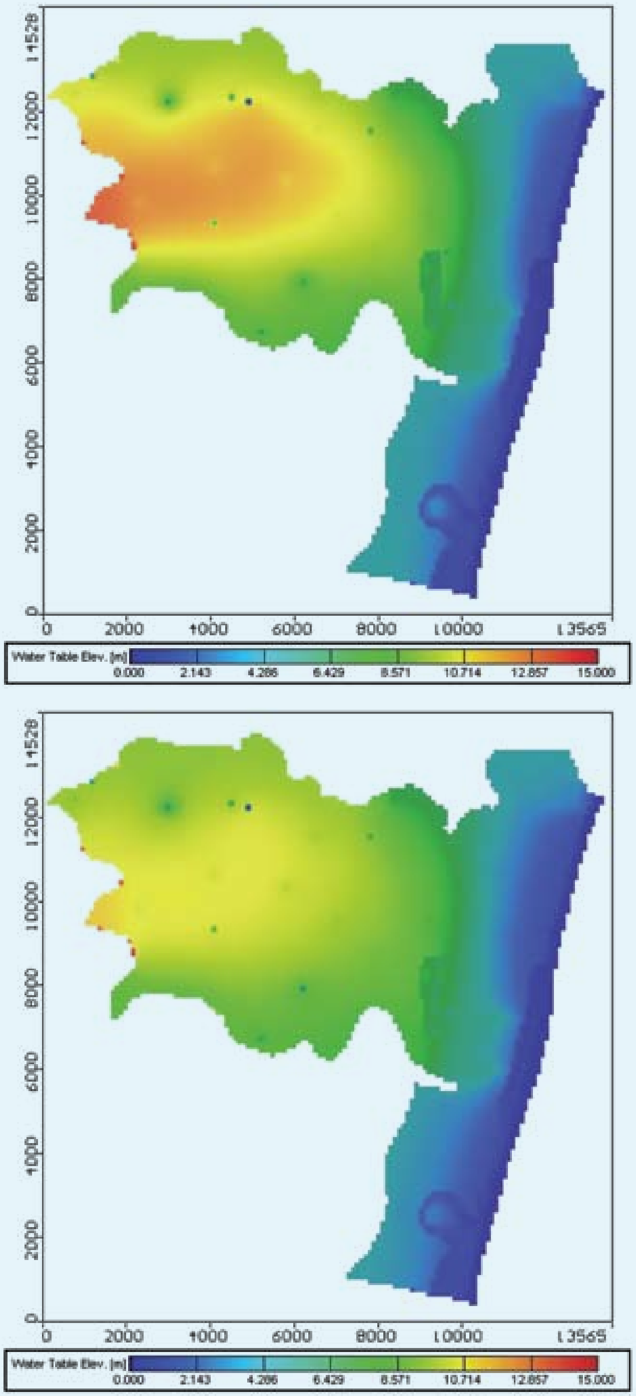


Fig. 12 : Trend of RWH impact during 2004 to 2012

MODEL PREDICTION FOR FUTURE

Prediction scenario on the effect of artificial recharge is carried out after the transient calibration (natural recharge). Improvement in rainfall recharge ratio (after provision of RWH) arrived from regression technique is used for giving the input in Modflow for recharge from 2012 to 2025.

In scenario 1 (S-1), the pumping is given for the future projected population and an average rainfall of 1400 mm is expected to come for recharging of aquifer. But in scenario 2 (S-2), the rainfall expected is less than 20% of average rainfall which in turn increase the pumping to 20% of scenario 1. In scenario 3 (S-3), the rainfall expected is more than 20% of average rainfall which in turn decrease the pumping to 20% of scenario 1. Then, the model is run to predict the response of aquifer for the above three scenarios. Figures 13 to 15 show the mapping of the simulated water table for scenarios 1 to 3 for the year 2025.



Figs. 13 &14 : Computed water level contours for Jan 2025 S-1 and S-2

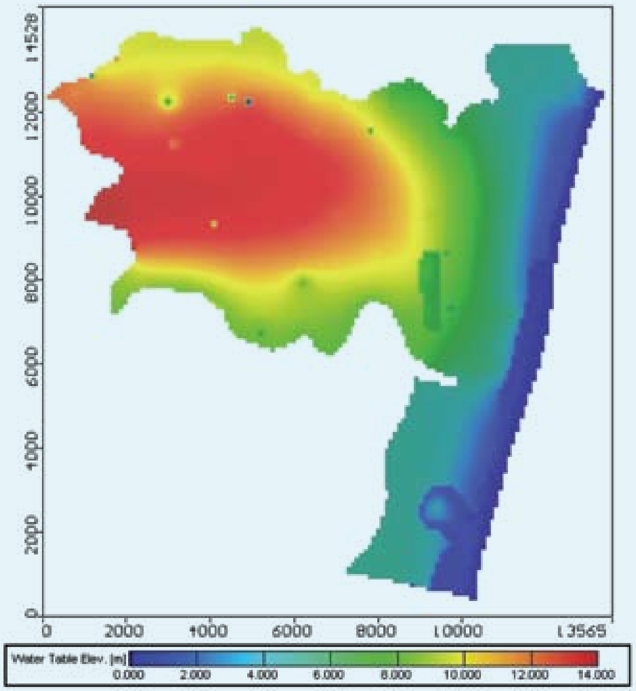


Fig. 15 : Computed water level contours for Jan 2025 (S-3)

In scenario 1 (Average rainfall occurrence), the water table elevation varies from 0 to 12m whereas in scenario 2 (rainfall occurrence is less by 20%), it varies from 0 to 10 m, showing a decrease of 2m. But, in scenario 3 (rainfall occurrence is more by 20%), water table variation is 0 to 14 m, indicating a water level rise of 2m. In these prediction scenarios, additional well drilling and groundwater pumping in the study area has to be monitored and controlled properly for a sustainable future. Efforts could also be in the direction of providing additional RWH structures to improve the water table.

CONCLUSION

In reality, it is not possible to see into the sub-surface and observe the geological structure and the groundwater flow processes. It is for this reason that groundwater flow models have been used to investigate the important features of groundwater systems and to predict their behavior under particular conditions. Hence in this study, a groundwater flow model is developed for the urban aquifer wherein the groundwater head over space and time are simulated. The computed groundwater head over space and time matches well with the observed groundwater head. The impact of RWH simulated through modeling shows the improvement of water table. But, the results from the future prediction scenarios indicate that water table will go down if pumping is increased and rainfall is decreased. Hence, there is a necessity to educate the society for proper usage of ground water and maintaining the RWH structures.

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INTERNATIONAL SEMINAR

GEOSYNTHETICS APPLICATIONS FOR MITIGATION OF NATURAL DISASTERS AND ENVIRONMENTAL PROTECTION

5-6 FEBRUARY 2015, BHUBANESWAR (ODISHA), INDIA

The catastrophic flood in Jammu & Kashmir and cyclone in Andhra Pradesh and Odisha are the worst recent disasters which have shaken the confidence of the nation in pursuing the infrastructure developmental models. In addition, the massive devastation which occurred in June, 2013 due to heavy rain and cloud burst followed by landslides, in Uttarakhand, has created a situation in the state which needs urgent attention.

Geosynthetics are now being increasingly used the world over for every conceivable application in civil engineering, namely, construction of dam, embankments, canals, approach roads, runways, railway embankments, retaining walls, slope protection works, drainage works, river training works, seepage control, etc. due to their inherent qualities. The role of Geosynthetics in engineering solution to the natural hazards, such as landslides, floods, earthquakes, cyclones, etc., needs to be stressed.

In the above context, Central Board of Irrigation and Power (CBIP) and the Indian Chapter of International Geosynthetics Society - IGS (India), are jointly organizing a Non Residential Seminar on “Geosynthetics Applications for Mitigation of Natural Disasters and Environmental Protection” at Bhubaneswar, during 5-6 February 2015, to emphasize the importance of geosynthetic for playing an import role, before and after such natural hazards.

REGISTRATION FEE

Member of IGS and CBIP	Indian Rs. 11,000+ Service Tax @ 12.36%
Non-Member	Indian Rs. 12,000+ Service Tax @ 12.36%
Researchers/Academicians/Students	Indian Rs. 6,000 + Service Tax @ 12.36%

In case of 04 or more nominees from an organization, one nomination will be allowed free registration.

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