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Research article

GROUNDWATER FLOW MODELING FOR WATERSHED MANAGEMENT: AN APPLICATION IN HARD ROCK TERRAIN OF INDIA

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ABSTRACT: Modeling of groundwater flow in watersheds is of great concern in characterizing the hydrogeological environments. This paper presents an application of groundwater flow model using the finite difference method, to simulate flow conditions. Detailed studies have been conducted at Lokapavani micro watershed which is located at Karnataka state, India. Results from this computation served as a methodology for analyzing the groundwater behavior at micro level. During the modeling procedures, it has been found that the head changes in the aquifer system of watershed at any specified time is a function of various aquifer characteristics. These changes are obtained by solving the equation of flow through porous media. The output obtained from this model is of practical application to hydrogeologists and similar stake holders for applying appropriate aquifer management practices.
Keywords: Micro watershed; Groundwater Model; Finite difference method; Lokapavani

INTRODUCTION

Groundwater is a major source of water for domestic and agricultural requirements in many hard rock terrains. The abstraction of groundwater has been found increased tremendously in the last two decades due to the increasing demand to meet the agricultural needs in particular in India. The poor water resources management leads to the deterioration of aquifers. Groundwater modeling techniques help to simulate the behavior and flow system to evaluate the water balances, which is important in the resources management. [24, 16, 17, 14, 13, 1, 9, 10, 11, 4, 26, 19, 22, 23, 27, 2, 3, 5, 6, 7, 8] have applied modeling techniques and analyzed few groundwater systems in India.

An attempt has been made in this study to simulate the groundwater system of Lokapavani micro watershed by constructing and operating a mathematical model, which assumes the appearance of the actual aquifer behavior.

About the Study Area

Lokapavani watershed is tributary of the Cauvery river and has its source at Honakere Hobli, Mandya district of Karnataka, India. The watershed spreads across latitude 12^0 25' and 12^0 48' North and longitudes 76^0 37' and 76^0 46' East (Figure 1). This is a perennial stream in the River basin of Cauvery. Geologically, the formations belong to the most ancient age, which are divisible into two groups as Dharwar schist as narrow linear belts and the peninsular gneisses / granites as hills.

The year may be divided in to four climatic seasons – February (dry with clear bright weather); March-May (hot); June-October (South west Monsoon) and November Retreating / Post Monsoon.

Groundwater Modeling

The process of mathematical modeling is comprised of four fundamental steps namely (i) formulation, (ii) approximation – transformation, (iii) computation and, (iv) application. Formulation refers to the process of deriving or selecting the basic equation(s) governing the flow of groundwater in the system, with the domain specifications and initial boundary conditions.

Approximation refers to the selection of a numerical method which can be used to solve the system of algebraic equations. Finite–Difference (FD). Finite Element (FE) and Integrated Finite – Difference (IFD) methods are some of the widely used concepts in modeling the groundwater systems.

The most important part of computation step refers to the process of obtaining a solution to the equations by using appropriate modeling. The application part of the groundwater modeling includes calibration or history matching of the observed and simulated heads, sensitivity analysis and prediction. Table 1 shows the some of the selected numerical methods adopted in groundwater modeling using Finite Difference method [12].

Table 1. Finite Difference Techniques for Solving Groundwater Flow Problems

Method	Description	Time – Step Restriction	Suitability
Forward difference (Explicit)	H (i,j,k+1) is calculated directly from H(i,j,k), H (i-1,j,k) and H(i,j-1,k). Effect of any change only spreads one mesh interval per time-step.	$\Delta t<\Delta X^2S/4T$	Short period analysis in unconfined aquifers when boundaries do not have any dominant effects
Backward difference (Implicit)	H(i,j,k+1) depends on the known value H(i,j,k) and the unknowns H(i,j+1, k+1), H(i,j,k+1), H(i-1, j,k+1) and H(i+1, j,k+1). This leads to simultaneous equations that can be solved using successive over relaxation.	None	Any type of problem, computing efforts is significant
Alternating Direction Explicit (ADE)	Two step procedure, uses a form of alternating direction techniques. The effect of a charge spreads across the field by the way of scanning the nodes.	$\Delta t<\Delta X^2S/T$	Aquifers in which boundary effects are significant. Not suitable for logarithmic time increments `
Iterative Alternating Direction Implicit	Two step procedure. In the first step, equations are implicit in x-direction and in the second step, equations are implict in y-direction. The sets of equations are solved by an interactive technique.	None	Any type of problems; suitable for log time increments; much computational time needed

RESULTS AND DISCUSSION

The groundwater flow model of Lokapavani micro watershed has been developed using standard finite difference techniques. The digital simulation model used in this study computes the head changes in the aquifer system at any specified time as a function of the various aquifer characteristics. These changes are obtained by solving the equation of flow through porous media. Although numerous analytical techniques exist, a digital model is necessary to treat the complex boundary conditions, aquifer heterogeneity and scale of the aquifer system. The governing equation of groundwater flow in Lokapavani micro watershed and its solution strategies have been discussed in this work. The partial differential equation (PDE), governing the flow of groundwater in a non-homogeneous, anisotropic aquifer, where the vertical components of flow are small to be neglected (Prickett and Lonnquist, 1971; Rushton and Redshaw, 1979) is

$$\delta/\delta x\,(Tx\ \delta h/\delta x) + \delta/\delta y\,(Ty\ \delta h/\delta y) = s\ \delta h/\delta t \pm w(x, y, t) \ldots\ldots\ldots..(1)$$

Where, Tx and Ty are the transmissibility parameters in x and y coordinates (L^2/T); 's' is the appropriate storage coefficient, 'h' is the hydraulic head (L); 't' is the time increment (T) and 'w' is the fraction of recharge or discharge (L/T) with reference to space and time. The general solution of equation (1) does not exist. The approximate solution of the equation is obtained by numerical methods like finite – difference method has been adopted in this study.

Finite – difference method is the process of replacing the partial derivatives at a point by the ratio of changes in variables over a finite interval. Both time and space variables are treated as discrete parameters. For this, the region covered by the function must be subdivided into a large number of grid blocks as shown in Figure 2. The values of all variables that best represent the condition of the grids are assigned to nodes which are located at the centers of sub-regions. The distance between the nodes is represented by Δx and Δy in x and y directions. This shows the transient flow conditions depicting the head distribution at (k) and (k+ 1) time levels. Subscripts 'i' and 'j' are used to index the row and column of a node and 'k' is the index of time.
The PDE (Partial Differential Equation) of backward difference (Implicit) formulation of equation (1) becomes,

$$\delta/\delta x\,(Tx\ {}^{\delta h}k+1/\delta x) + \delta/\delta y\,(Ty\ \delta h\ k+1/\delta y) = S\ \delta h\ k+1-\delta h\ k/\delta t \pm W \ldots\ldots (2)$$

On modifying the equation (2) by using the notations of Figure 2, gives equation (3).

$$AH(i+1, j, k+1) + BH(i, j-1, k+1) + CH(i-1, j, k+1) + DH(i, j+1, k+1)$$
$$-(A+B+C+D)\,H(i, j, k+1) = F\,(H(i, j, k+1) - (H(i, j, k)) \pm W(i, j) \ldots\ldots (3)$$

Solving all the equations at each time step is a time consuming process which can become manageable only by adopting iterative techniques. The method which has proved to be convenient for groundwater flow problems is the technique of Successive over Relaxation (SOR) [Rushton and Redshaw, 1979].

In describing the SOR method, further it is helpful to denote a coefficient E as,

$$E = A+B+C+D + S(i,j)/\delta t = A + B + C + D + F \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ (4)$$

Equation (3) can be written in a form similar to that of the explicit procedure as,

$$H(i, j, k+1) = [AH(i+1, j, k+1) + BH(i, j-1, k+1)$$
$$+ CH(i-1, j, k+1) + DH(j, j+1, k+1)$$
$$+ FH(i, j, k) \pm W(i, j)]/E \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (5)$$

This equation allows the direct computation of head at (k+1) time level but it depends on the other heads of the same time step which, in the early stages of the computation, might not have reached their correct value. Therefore, the head distribution given by the use of equation (5) will be an under estimate of the true values. In order to overcome this an over relaxation factor of 'W' (Remson et al, 1965) is introduced to equation (5) so that the new approximation to the potential is given by,

$$H(i,j,k+1,M+1) = H(i,j,k+1,M) + W\,\Delta H(i,j,k+1, M+1, M) \ \ldots\ldots\ldots\ (6)$$

Where, ΔH (i,j, k+1, M+1,M) is the change in potential between (M) and (M+1) iterations. Equation (6) is used at each node in turn, as the iterations proceed; convergence to a steady value is achieved. The over relaxation factor normally ranges from 1.0 to 2.0 (Remson et.al, 1965). After several trial runs with the computer model, a factor of 1.5 has been taken and has been used in this study.
In order to test the convergence, the error in satisfying the finite difference form of the differential equation (2) is calculated from equation (5) as,

$$ERROR = AH(i+1, j+1) + BH(i, j-1, k+1) + CH(i-1, j, k+1)$$
$$+ DH(i, j+1, k+1) - FH(i,j,k+1) \pm W(i,j) \ \ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

An error criteria of 0.01 has been has used in the present analysis. Iterations continued in the process till the computed error value became lesser than this amount. A two dimensional groundwater flow model written in GW BASIC based on [21] has been utilized for computing the nodal yields, flows and permeability values. Each step of the computation used around 61 days time step and gives the result of water level distribution at the first day of every alternate month. The nodal transmissibility values are being refined at all the steps to adopt transient conditions.

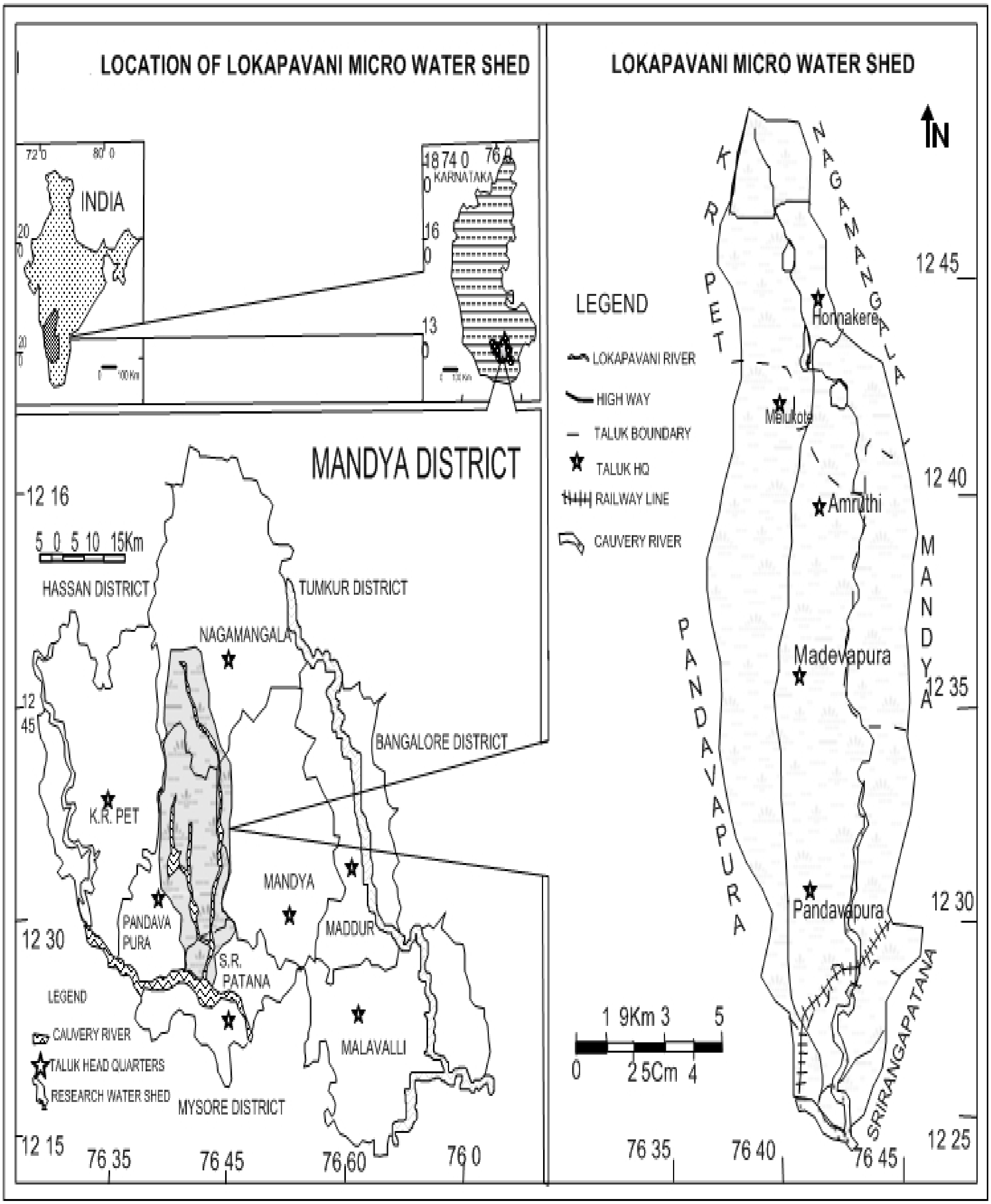

Figure 1. Location of the study area

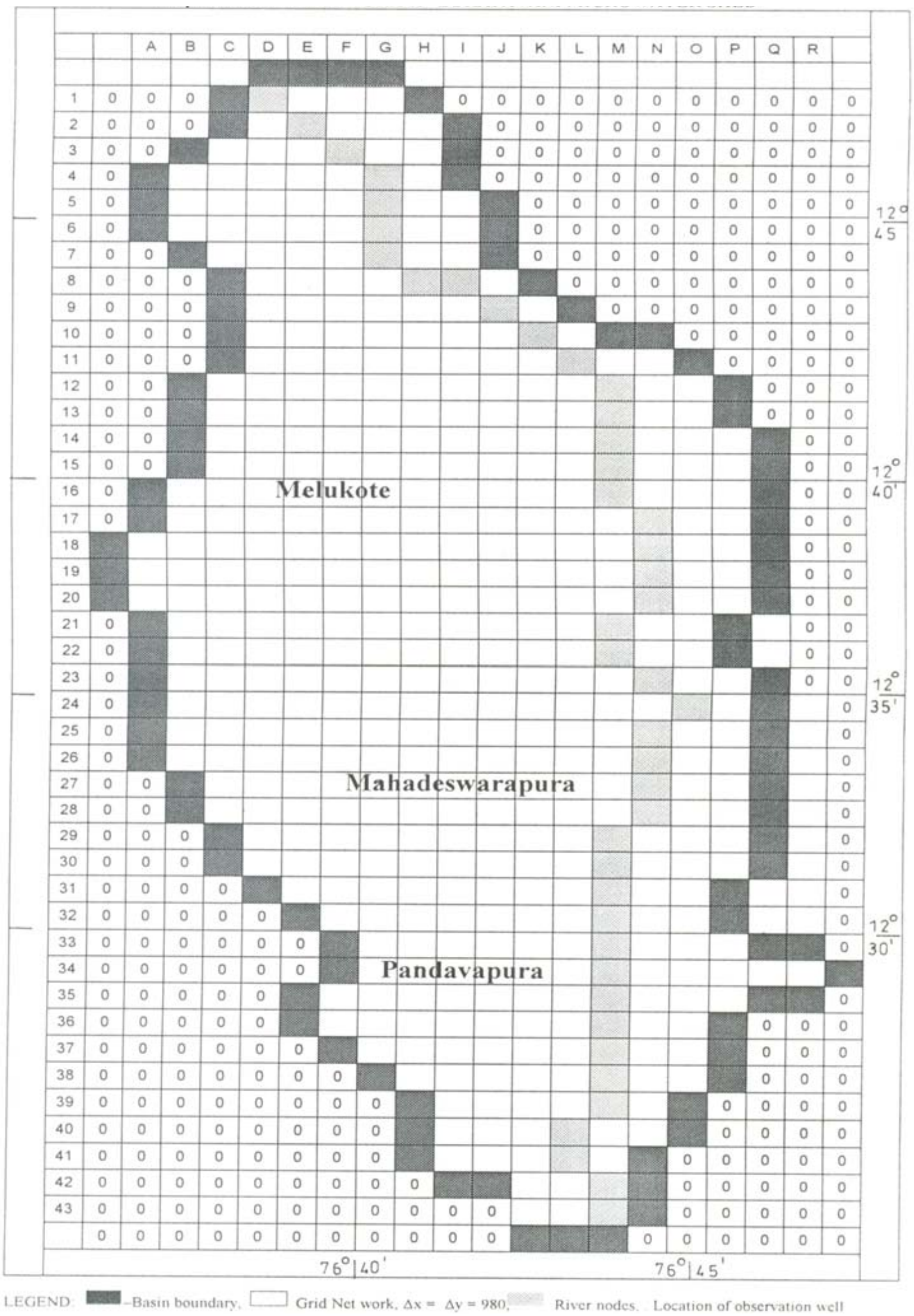

Figure 2. Nodal network of Lokapavani watershed

The method of successive over relaxation used in backward difference (implicit) formulation has been used completely for simulating the aquifers of Lokapavani micro watershed, as the method is better than the forward difference (explicit) formulation and used lesser computational time.

In order to avoid manual plotting of observed and predicted heads and to save the time lapse between successive runs in the computer, options have been included to input systematic water level data of wells falling on or adjacent to the node. The differences between predicted and observed head values have been taken as output at all the steps of the model. Slight modifications are necessary at one place or the other in the program when it is to be used for other watersheds.

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1		0		915	915	915	915	915		0	0	0	0	0	0	0	0	0	0	
2		0		915	910	910	910	910	910		0	0	0	0	0	0	0	0	0	
3		0		915	950	900	900	900	900		0	0	0	0	0	0	0	0	0	
4		0		915	900	900	885	885	885	885		0	0	0	0	0	0	0	0	
5			917	915	890	885	879	879	879	880		0	0	0	0	0	0	0	0	
6		915	910	900	989	880	875	879	875	875	880		0	0	0	0	0	0	0	
7		910	910	890	885	879	875	879	870	870	870		0	0	0	0	0	0	0	
8			900	890	885	879	875	860	865	865	865		0	0	0	0	0	0	0	
9		0		885	882	880	871	865	855	849	849	850		0	0	0	0	0	0	
10		0		880	882	879	871	865	849	848	848	848	848			0	0	0	0	
11		0		880	879	875	875	860	849	847	846	846	848	849	849		0	0	0	
12		0		880	875	876	875	855	849	845	840	836	840	822	830	840		0	0	
13		0		900	915	889	865	850	849	841	837	819	819	819	819	826	826		0	
14		0		915	915	915	889	880	846	840	830	819	815	815	810	810	819		0	
15		0		916	915	915	879	830	845	830	819	810	810	789	785	789	800		0	
16			915	915	915	911	885	849	830	819	815	790	799	780	782	783	789		0	
17			910	900	900	885	850	820	815	810	780	788	789	782	782	782	782	781		
18		900	900	880	880	845	820	818	775	789	785	780	780	781	781	781	782	782		
19		885	869	845	820	815	788	775	771	772	733	775	789	780	780	780	781		0	
20		845	845	815	790	788	787	771	768	768	769	769	762	779	769	770	771		0	
21		815	789	785	786	785	779	779	769	769	760	760	760	759	760	765	765		0	
22		785	789	784	782	779	770	769	760	759	759	759	758	758	759	759	760		0	
23		780	780	780	778	765	760	759	759	757	756	750	745	750	750	757	760		0	
24			778	772	760	759	759	750	750	750	745	743	740	745	745	750	758		0	
25			769	760	760	755	750	745	745	745	745	740	735	735	735	735	736	736		
26			760	759	757	755	748	740	740	740	740	735	730	730	730	730	735	736		
27			758	750	745	742	738	734	738	735	735	730	729	728	729	729	730	735		
28			748	740	739	739	733	733	732	730	729	729	728	728	728	728	729	729		
29		0		740	733	738	731	730	730	729	728	729	725	726	718	719	729	730		
30		0		740	735	730	730	729	727	728	729	729	720	720	716	725	728	729		
31		0		739	731	729	729	725	720	722	725	720	712	714	716	720	728		0	
32		0	0			728	726	725	719	719	714	714	713	711	712	715	715		0	
33		0	0	0	0		715	713	713	713	713	712	711	711	711	711	0		0	
34		0	0	0	0		712	712	712	712	711	710	710	710	710	711	711	711		
35		0	0	0	0		711	712	712	711	710	709	709	709	709	710	711	711	711	
36		0	0	0	0		711	711	711	710	709	708	708	708	708	709	710	710	71	
37		0	0	0	0		710	710	710	709	707	705	705	706	706	708	710			
38		0	0	0	0	0		710	709	708	708	704	707	706	707	707		0	0	
39		0	0	0	0	0	0		708	707	706	703	703	705	706	706		0	0	
40		0	0	0	0	0	0	0		704	703	703	702	703	703	703		0	0	
41		0	0	0	0	0	0	0		704	702	701	701	702	702	702		0	0	
42		0	0	0	0	0	0	0		702	701	701	701	701	701		0	0	0	
43		0	0	0	0	0	0	0	0				701	701		0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	

12°45' | 12°40' | 12°35' | 12°30'

76°|40' 12°|45'

LEGEND: –Basin boundary, Grid Net work, Δx = Δy = 980

Figure 3. Initial waterlevel of Lokapavani watershed

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1		0		150	100	150	150	150		0	0	0	0	0	0	0	0	0	0	
2		0		150	150	100	100	100	100		0	0	0	0	0	0	0	0	0	
3		0		150	150	100	100	100	100	150		0	0	0	0	0	0	0	0	
4		0		100	150	150	150	150	150	100		0	0	0	0	0	0	0	0	
5			100	100	150	150	100	100	100	100		0	0	0	0	0	0	0	0	
6		100	100	100	100	100	100	100	100	100	100		0	0	0	0	0	0	0	
7			100	100	100	150	150	150	100	100	100		0	0	0	0	0	0	0	
8			100	100	150	150	150	150	150	100	100		0	0	0	0	0	0	0	
9		0		150	150	150	100	100	100	100	150	150		0	0	0	0	0	0	
10		0		150	150	150	100	100	100	100	100	150	150		0	0	0	0	0	
11		0		100	100	100	100	100	100	100	100	100	150	150			0	0	0	
12		0		150	150	100	100	100	100	150	150	150	100	150	150	150		0	0	
13		0		150	150	100	100	100	100	150	150	150	150	150	100	50	50		0	
14		0		150	100	100	100	100	100	100	150	150	150	150	50	200	200		0	
15		0		100	100	100	100	100	100	150	150	100	100	100	150	150	100		0	
16			100	100	100	100	100	100	150	150	150	100	100	100	150	150	100	100		
17			100	100	100	100	100	150	150	150	150	150	150	150	150	150	100	100		
18		100	100	100	100	100	150	150	150	50	50	50	50	150	150	150	100	100		
19		100	100	100	100	150	150	150	50	50	50	50	50	50	150	150	100	100		
20		100	100	100	100	150	150	150	50	50	50	200	200	50	150	100	100		0	
21		100	100	100	150	150	150	150	50	50	200	200	200	200	150	100	100		0	
22		100	100	100	100	150	150	50	50	50	50	200	200	150	100	45	45		0	
23		100	100	100	100	45	100	50	150	150	150	150	150	150	100	45	45		0	
24			100	100	100	45	45	100	150	150	150	150	150	100	100	100	100		0	
25			150	150	150	100	45	45	100	100	100	100	100	100	100	100	100	100		
26			150	150	150	100	45	45	45	45	100	100	100	100	100	100	100	100		
27			100	150	150	150	100	100	45	100	100	100	100	100	100	100	100	150		
28			100	100	50	200	200	150	150	100	100	100	100	100	100	150	200	200		
29			100	100	150	50	200	200	50	150	100	100	100	100	150	200	200	200		
30		0		150	50	50	200	200	50	150	150	100	100	100	150	45	200	200		
31		0		150	50	200	200	50	150	150	100	100	100	100	150	50	200	200		
32		0		50	50	200	200	50	150	150	100	100	100	150	150	50	50		0	
33		0	0			200	200	200	50	150	150	100	100	150	150	150	50		0	
34		0	0	0	0		200	200	150	150	100	100	150	150	150	150	150	150		
35		0	0	0	0		200	200	200	150	100	100	100	150	150	150	150	50	50	
36		0	0	0	0		200	200	200	150	100	100	100	150	150	150	150	150		
37		0	0	0	0		200	200	200	50	100	100	100	150	150	150	150		0	
38		0	0	0	0	0		200	200	50	150	100	100	100	150	150		0	0	
39		0	0	0	0	0	0		200	50	150	100	100	100	100	100		0	0	
40		0	0	0	0	0	0	0		50	150	100	100	100	100	100		0	0	
41		0	0	0	0	0	0	0		50	150	100	100	100	100	100		0	0	
42		0	0	0	0	0	0	0		50	150	100	45	45	45	100		0	0	
43		0	0	0	0	0	0	0	0				45	45			0	0	0	

12° 40' — 12° 40' — 12° 35' — 12° 30'

76° 40' — 76° 45'

LEGEND: ■ – Basin boundary, □ Grid Net work, Δx = Δy = 980

Figure 4. Aquifer transmissibility of Lokapavani watershed

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1		0		960	963	960	960	950		0	0	0	0	0	0	0	0	0	0	
2		0		950	953	962	979	957	940		0	0	0	0	0	0	0	0	0	
3		0		970	970	960	961	962	930	929		0	0	0	0	0	0	0	0	
4		0		975	971	962	930	920	915	910		0	0	0	0	0	0	0	0	
5			990	985	930	920	920	915	915	910		0	0	0	0	0	0	0	0	
6		990	1001	1010	931	920	862	907	910	910	913		0	0	0	0	0	0	0	
7		990	962	1010	950	948	950	930	920	899	890		0	0	0	0	0	0	0	
8			965	965	963	960	950	939	920	860	859		0	0	0	0	0	0	0	
9		0		985	985	960	940	940	985	870	852	850		0	0	0	0	0	0	
10		0		990	995	999	910	880	981	870	850	853	850			0	0	0	0	
11		0		960	947	880	880	930	910	874	850	834	828	830	830		0	0	0	
12		0		980	909	756	750	810	881	850	845	868	912	875	860	852		0	0	
13		0		1010	980	954	880	870	880	850	850	850	910	825	824	820	820		0	
14			1010	1016	1010	951	870	852	860	866	850	840	795	790	812	820	820		0	
15			1010	1013	1040	948	895	893	850	848	830	711	790	793	890	808	820		0	
16			980	980	970	1061	900	892	850	850	830	785	765	750	785	808	801		0	
17		900	910	950	910	1010	900	891	870	852	825	820	790	778	792	785	770	770		
18		900	900	910	900	900	900	850	760	751	760	825	779	770	755	783	770	770		
19		869	880	900	864	880	890	830	825	825	825	839	825	770	785	781	770	770		
20		869	864	864	850	840	832	830	825	820	795	794	790	753	745	766	770		0	
21		862	850	850	850	852	848	810	790	810	802	750	730	720	740	760	770		0	
22		850	830	833	825	850	850	790	780	790	780	735	718	720	730	750	770		0	
23		848	839	825	820	833	825	825	825	865	780	769	720	720	740	769	770		0	
24		821	820	820	820	820	820	820	820	864	774	750	720	725	735	756	760	760		
25			785	785	808	820	820	820	820	825	790	735	734	740	742	726	730	735		
26			790	796	796	808	785	784	785	784	770	735	734	749	740	720	745	745		
27			790	796	783	783	775	770	770	770	770	755	755	745	733	742	745	745		
28			790	795	775	783	775	770	760	760	750	750	750	730	733	733	760	760		
29			780	780	771	775	769	760	751	750	750	745	733	730	730	740	764	740		
30		0		771	755	765	754	750	750	750	730	745	730	725	720	720	740	740		
31		0	0		755	755	750	750	750	750	730	738	730	725	724	720	720			
32		0	0	0		746	735	730	734	725	728	725	715	715	715	715	715		0	
33		0	0	0	0		730	730	725	710	715	715	709	709	709	709	715		0	
34		0	0	0	0		710	710	712	710	700	705	705	720	734	730	730	730		
35		0	0	0	0		710	710	710	700	700	705	705	718	705	700	720	734	730	
36		0	0	0	0		729	729	700	680	699	696	700	700	664	660	660	700	720	
37		0	0	0	0		729	700	675	675	690	696	690	690	679	675				
38		0	0	0	0	0		670	672	680	690	694	690	694	689	687		0	0	
39		0	0	0	0	0	0		680	680	690	690	685	670	686	680		0	0	
40		0	0	0	0	0	0	0		685	689	675	660	672	680	680		0	0	
41		0	0	0	0	0	0	0		686	684	682	679	673	673	673		0	0	
42		0	0	0	0	0	0	0		680	659	660	660	665	660			0	0	
43		0	0	0	0	0	0	0	0				660	660		0	0	0	0	

12° 45'
12° 40'
12° 35'
12° 30'

76° 40'   76° 45'

LEGEND: –Basin boundary, Grid Net work, Δx = Δy = 980

Figure 5. Aquifer basement topography of Lokapavani watershed

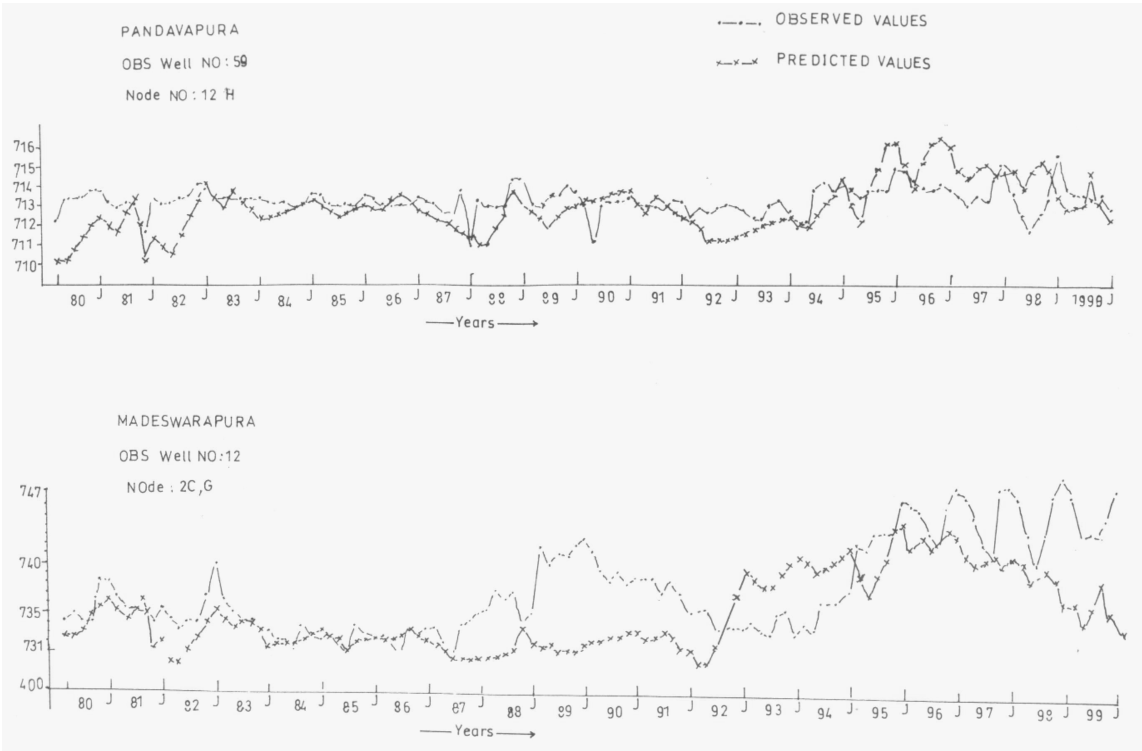

Figure 6. Simulated and observed water level hydrographs

During the model design, a finite – difference grid is superposed over the map of Lokapavani micro watershed. The aquifer is thus divided into volumes having dimensions mΔx Δy. Where 'm' is the thickness of the aquifer used in the model. The position of nodes can be identified by their column and row integer subscripts i.e., 'i' and 'j', starting from the left hand top corner. The network of this micro watershed model contains 18 columns and 43 rows amounting 774 nodes in which 108 are boundary nodes and 450 nodes lying within these boundary nodes are the active nodes of the model. As the basin is formed by an aquifer of extensive areal extent a grid spacing of $\Delta x = \Delta y$ = 980 m has been used in this study.

It is very essential in these techniques that the head computed for a node containing a pumping well is not the head in the well, but rather it represents an average hydraulic head for the entire nodal block. The basic assumptions of the present model for calculation of the head in a node are as follows:

1. The aquifer is unconfined in major part of the model bounded with an impermeable basement at depth; no flow along basin divide and in hilly and forested terrain.
2. Groundwater obeys Darcy's law and the flow is two-dimensional.
3. Transmissibility, Rainfall recharge in the system is not constant with space and time.
4. The interval of normal water table fluctuation has a fairly narrow range of depth and in this interval the change of hydraulic conductivity is very small and hence permeability in the vertical section is assumed to be constant.

The water level above MSL data of January 1980 forms the initial data (Figure 3) is used as input to the model. Zero transmissibility values have been assigned to all the nodes located outside the basin boundary and in the hilly and forested terrain (Figure 4). The nodal permeability values have been computed using the relation,

$$P(i, j) = TS(i, j) / (HJ(i,j)) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where P is the permeability (m/d), TS is the Transmissibility (m^2/d), HJ is the water level altitude above M.S.L. The storage coefficient values the best result at 0.01. Values obtained from geophysical sounding have been used in obtaining the aquifer basement depth (Figure 5).

The model calibration procedure is based on matching the simulated potentials with the observed ones by adjusting the various input parameters. Model calibration has been done in this study from 1980 to 1999. Figure 6 shows the simulated and observed well hydrographs of the present model at selected locations. It could be seen that both the graphs match very well and this gives a good indication of the overall accuracy of parameters used in the model. This program could further be used for predictions.

CONCLUSION

Finite difference techniques have been followed for developing the groundwater flow model for Lokapavani micro watershed. It has been observed that head changes in the aquifer system of watershed at any specified time is a function of various aquifer characteristics. These changes are obtained by solving the equation of flow through porous media. The groundwater flow model conducted in this study is an example of applying modelling techniques to watershed to help to understand the hydrogeological characteristics at micro level.

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