BUILDING A MODEL FOR THE GROUNDWATER MANAGEMENT IN RED RIVER DELTA PLAIN BY USING SOFTWARE VISUAL MODFLOW

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ABSTRACT

The Red river delta plain is largest economic, political, social and cultural centre of the country. Groundwater is a precious resource for the socio-economic development in the region. Groundwater management is a pressing task that requires a proper investment for ensuring the sustainable exploitation of this natural resource.

Based on the previous and current research data, the authors have built a model by Visual MODFLOW software. The model includes 4 layers. Rivers, lakes and coastlines are simulated by different boundary conditions depending on the hydrogeologic characteristics and the hydraulic relationship with groundwater. The finite difference grid size of the model is 1000m by 1000m. The model is made accurate by calibration based on the regime monitoring data of nine State monitoring lines from 1998 to present. The result of model allows for management of wellfields, the current groundwater exploitation wells with total production discharge of 700000m^3/day as well as planning, designing new well fields. The last but not the least, it is also a good data base on groundwater resource in the entire delta plain.

1. INTRODUCTION

The Red River delta plain is largest economic, political, social and cultural centre of the country. Although the area of the plain is not large about 17000-km2-population density is the highest density in the whole territory of the country - 1124 pepole/km2 and the population is about 20 mil. people. Large amount of groundwater has been abstracting for dosmetics and development. Nowadays, in Hanoi and some towns such as Ha Dong, Son Tay, Vinh Yen, Phuc Yen, Bac Ninh, Hung Yen water supply is mainly from groundwater resource. That why building a model for management, sustainable exploitation of this natural resource is necessary in this stage

Red River delta plain belongs to wet monsoon tropical climate zone with two distinguished seasons. Rainy season lasts from May to October. Dry season takes place from November to April next year. Average annual rainfall is in range 1033.1mm to 2338.7mm. Evatransporation varies from 828.2 mm to 1057.1 mm. There exits two river systems: Red River system and Thai Binh river system. Coastline distributes in east ant southeast of the plain and starts from Quang Yen to Nga Son with distance of 200 km.

Up to the end of 2000, total of groundwater exploitation in the entire plain is about 700000 m3/day. At the same time wastewater from industrial bases, rural and resident places have been effected to quality and quantity of groundwater. In Hanoi only there is about 100000m3/day wastewater from industrial bases and 170000-m3/day wastewater from dosmetics.

2. BUILDING A MODEL BY VISUAL MODFLOW SOFTWARE

2.1 Introduction of Visual MODFLOW

Visual MODFLOW is software to be used for simulation of ground water environment. It views a three dimensional system as a sequence of layers of porous material. Waterloo Hydrogeologic, Inc. Waterloo, Ontario, CANADA makes this software.

The three-dimensional movement of groundwater of constant density through porous material may be described by partial-differential equation

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-W = Ss\frac{\partial h}{\partial t} \quad (1)$$

Where

- K_{xx} , K_{yy} , K_{zz} are values of hydraulic conductivity along the x, y and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (Lt^{-1});
- h is the potentiometric head (L)
- W is a volumetric flux per unit volume and represents sources and or sink of water (t^{-1}).
- S_s is the specific storage of the porous material (L^{-1}) and
- t is time (t).

Equation (1), together with specification of flow and/or head conditions at the boundaries of an aquifer system and specification of initial head conditions, constitutes a mathematical representation of a groundwater flow system. A solution of equation (1) is an algebraic expression giving h(x,y,z,t) such that, when the derivatives of h with respect to space and time are substituted into equation (1), the equation and its initial and boundary conditions are sastified.

2.2 Building a groundwater model of Red River delta plain

Based on hydrogeologic condition the following hydrogeological layers are divided as follows:

Layer 1: is upper layer consists of deposits of Thaibinh formations (aQ_{IV}^{3}*tb*, amQ_{IV}^{3}*tb*, mQ_{IV}^{3}*tb*, mvQ_{IV}^{3}*tb*, bmQ_{IV}^{3}*tb*), Haihung formations (bmQ_{IV}^{1-2}*hh*, amQ_{IV}^{1-2}*hh*, mbQ_{IV}^{1-2}*hh*, lbQ_{IV}^{1-2}*hh*). They are clays, sandy clays and clayey sands.

Layer 2: is Holocene aquifer (qh) and consists of deposits of Haihung formation (aQ_{IV}^{3}*tb*, aQ_{IV}^{1-2}*hh*, amQ_{IV}^{1-2}*hh*). Strata is mainly fine to medium sands and clayey sand.

Layer 3: consists of deposits of Vinhphuc formations (mQ_{III}*vp*, amQ_{III}*vp*, bmQ_{III}*vp*). It is clays and sandy clays

Layer 4: is Pleistocene aquifer and consists of Vinhphuc formation ($aQ_{III}^{2}vp$), Hanoi formation ($aQ_{II-III}hn$) and Lechi formation ($aQ_{I}lc$). Strata is medium to coarce sand with gravel and pebbles.

In order to simulate the study area the domain is divided into finite difference grids with size of 1000m by 1000m.

There is about 1000 hydrogeological investigated wells in the plain. 350 wells of them are to be tested for hydogeological parameters of Pleistocene aquifer (layer 4), 450 wells of them are to be tested for hydrogeological parameters of Holocene aquifer (layer 2). Left wells and some points are to be sampled or tested for hydraulic conductivity of layer 1 and 3.

For 2 main aquifers, based on previous and current researches of hydogeological conditions and hydraulic relationship between run-off system and groundwater, boundary conditions are simulated.

At the boundary of a contact between crystallized rocks and aquifers in the northeast plain there exits inactive cells or no flows and also limitation of domain. In

the west plain, aquifer system is recharged unequally along the boundary from karstic rocks (carbonate formation) in outside domain. Rivers (Red river system) and Thaibinh river system) and lakes (Damvac, West lake...) and coast line are simulated by General Head Boundary (GHB) with the values of head from long term monitoring stations and conductance of bottom (C) deepening on researched and surveyed results of relationships between groundwater and them.

Nowadays, there exits nine State monitoring lines from 1998 and they distribute all over the plain. Monitoring data of quality, quantity such as groundwater, surface water levels and some kinds of pollution are collected. They are good database for calibration and completion of the model.

As indicated above, groundwater has been exploited for water supply for Hanoi and some towns. It is extracted mainly from low aquifer (Pleistocene aquifer). According to statistics amount of groundwater exploitation showed as follows:

Table 1. Groundwater exploitation from 1993-1998*

Year	1993	1994	1995	1996	1997	1998
Pumping rate (m^3/ng)	481391	517991	542663	554103	569643	593173

** The figure is only for Pleistocene aquifer, for Holocene aquifer private wells are extracted and not staticsticted*

2.3 Calibration

To calibrate the model, groundwater levels of layers in first quarter of 1993 is assigned as initial head (initial boundary). They are measured at 83 points of State monitoring lines for both aquifers. Time duration for calibration last from fist quarter of 1993 to fourth quarter of 1998. After many trial-and-error simulations by changing permeability, recharge rate, storage coefficient and the boundaries the model most fitting the reality has been built. This can be seen from the water level distribution in Pleistocene aquifer and Holocene aquifer at the time duration above (see fig. 1). Errors of all monitoring points at any time between observed heads and computed heads are less than 1.0m. If combination with budget solutions of IN-OUT ≈0% the model are corrected and can be used for management and designing.

After calibration, boundary conditions, values of recharge and evapotranspiration, hydrogeological parameters are corrected. Hydraulic conductivity and specific storage are divided into following zones:

of hydraulic conductivity:

- Layer 1 (4 zones) 0.05; 0.7; 3; 7 m/day
- Layer 2 (4 zones) 7; 15; 30; 50 m/day
- Layer 3 (6 zones) 0.0001; 0.001; 0.005; 0.05; 3; 7 m/day
- Layer 4 (7 zones) 17; 30; 35; 50; 60; 90; 100 m/day

of specific storage:

- Layer 2 or Holocene aquifer: (3 zones) 0.0005; 0.001; 0.005
- Layer 4 or Pleistocene aquifer (4 zones) 0.0001; 0.0002; 0.0003; 0.0005.

3. IMPLEMENTATION OF THE MODEL TO GROUNDWATER MANAGEMENT.

Results of prediction of groundwater exploitation by above corrected model based on following planing alternatives:

3.1 Planing by authorities for water supply

Based on planing by authority of provinces, cities such as Hanoi, Vinhyen, Bacninh... as well as strategy for urban water supply up to 2015 by Construction Ministry, the result of predictions shows that total amount of groundwater supply up to 2015 of 1.129.956 m3/day is sartified. Maximum dropped water levels (m.s.l) are Mai Dich wellfield: -18.19m, Hadinh wellfield: -17.94m, Ngocha wellfield: -17.14m. Because the almost of high dropped water levels distributes in Hanoi some environmental impacts may be effected such as land subsidence, pollution and degradation of wells.

3.2 Planing based on sustainable groundwater exploitation.

In order to prevent highly dropped water levels in some wellfields and optimization of groundwater resources in the plain we suggest a plan for groundwater exploitation based on following points:

- In Hanoi pumping rate of some wellfields around centre city should be reduced and wellfields along Red river and North part of Hanoi should be decreased.

- For rural water supply some wellfields should be planed in order to mitigate bad environmental impact due to exceeding private wells from Holocene aquifer.

The result of prediction shows that total amount of groundwater supply up to 2015 of 1.210.322 m3/day is sastified. Maximum dropped water levels (m.s.l) are Mai Dich wellfield: -13.23m, Hadinh wellfield: -13.99m, Ngocha wellfield: -13.15m. These mean that some high dropped water levels are mitigated and groundwater resource is supplied for more residents especially in rural areas.

4. CONCLUSIONS

The following conclusions may be made from the model built for ground water in Red River delta plain by numerical modeling using VISUAL MODFLOW :

Hydrogeological conditions and boundary conditions in the study area are very complicated so that numerical modeling method is good tool to manage, plan and design groundwater resource.

Some implementations of the model show that it very easy to predict ground water exploitation to control ground water environment as well as upgrade groundwater database.

5. REFERENCES

Pham Quy Nhan. 2000. *Groundwater resource in Red River delta plain* (Ph.D. thesis) in Vietnamese. Library of Hanoi University of Mining and Geology.

William C. Walton. 1970. *Groundwater resource evalution*. McGraw-Hill Book Company. Newyork.

Mary P. Anderson; William W. Woesseer. 1992. *Applied ground water modeling.* Academic Press., Inc.; Newyork.

Herbert F. Wang; William W. Woesseer. 1982. *Introduction to groundwater modeling*. Academic Press., Inc.; Newyork.

Nilson Guiguer and Thomas Franz. 1996. *Visual MODFLOW. Version 2.00*. Waterloo Hydrogeologic Software. Toronto.