EVALUATION OF GROUND WATER EXPLOITATION RESERVES IN VINHYEN TOWN BY NUMERICAL MODELING

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ABSTRACT

Nowadays, demand of water supply for Vinhyen town and the surrounding area is increasing rapidly and ground water resource is main source for abstraction. For fist stage, 15000m^3 ground water should be foreseen. Hydrogeological conditions and boundary conditions in the study area are very complicated so that numerical modeling method is good tool to predict ground water exploitation reserves. By numerical modeling using VISUAL MODFLOW a result of prediction shows that the location of wells in Hopthinh and Damvac wellfield can meet the demand for water supply and by the end of project time, dynamic water level is still higher permissible groundwater level for it's sustainable exploitation.

1. INTRODUCTION

The study area is located on the northwest of Hanoi, with the area of about 400km^2 in the intermit zone between Tamdao mountainous area and plain area. Nowadays, demand of water supply for Vinhyen town and surrounding area is increasing rapidly and ground water resource is main source for abstraction. For fist stage, 15000-m3 ground water should be foreseen.

Study area 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. Some characteristics can be seen from the observation data at Vinhyen meteorological station measured from 1993 to 1998: Average annual rainfall is 1619.1mm, maximal up to 2029.5mm (1997), and minimal 1131mm (1995). Rainfall concentrates mainly in July and August. Maximal monthly rainfall is 653mm (10/1998). Minimal monthly rainfall is 3.2mm (12/1995). Stream system has been relatively highly developed in the study area; the specific examples are the Red river, Phoday river and Tannguyen river.

2. HYDROGEOLOGICAL CONDITIONS

The following hydrogeological units may be divided based on the existing references and update investigation of hydrogeology:

- Holocene pore water bearing aquifer (Q_{IV}).
- Upper Pleistocene impermeable layer ($Q_{III}\ vp_2$).
- Upper Pleistocene pore water bearing aquifer ($Q_{III}\ vp_1$).
- Upper-Middle Pleistocene Impermeable layer ($Q_{II-III}\ hn_2$)
- Middle-Lower Pleistocene pore water bearing aquifer Holocene (QII-III hn1).

2.1 Holocene aquifer (Q_{IV}).

Aquifer Q_{IV} distributes along rivers and streams. The widest area distribution of this aquifer is along the Red river from Caodai commune to Vanha commune and is of width 5-6km. This aquifer consists of clayey sands, sandy clay of darkish brown color, in the lower part are fine and middle sands of brown colour. The Thickness of aquifer Q_{IV} is in the range 1-15 m. The recharge of the aquifer is mainly from the rain and surface water. The water level fluctuation depends mainly upon the seasons and the hydrological factors. The pumping tests made in the hand dug wells gave the average permeability K= 8m/day. The observation water level data in the wells show that the monthly average water level is from +6.76m to +13.66m with high water level fluctuation the maximum of which ΔH_{max}=3.3-7.9m

2.2 Upper Pleistocene impermeable layer ($Q_{III}vp2$)

This layer is widely spreading is the study area. It belongs to the upper layer of Vinhphuc formation (aQ_{III} vp_2). It is exposed mainly in the central part of the study area. It disappears in north and northwest part what has created hydrogeological windows through which the rain and surface water penetrates into the aquifer and lower aquifers. The materials are clay and sandy clay mixed with laterited grits, what makes them colorful. The laboratory test results gave the average permeability K_{tb}=0.000544 cm/s. The thickness is from 2.2m to 23.4m, in average 7.61 m.

2.3 Upper Pleistocene aquifer ($Q_{III}vp_1$)

This aquifer is widely spreading and consists of deposits of the lower part of Vinhphuc formation, mostly is covered, and is exposed only in the north part. The deposits are sands, grits and gravels, in some places small pebbles. The thickness is from 2.4 to 28.87m, in average 10.21m. The pumping tests in wells LK143, LK163 (outside the study area) and HT4B (inside the study area) gave pumping rates Q=1.46-7.7 l/s, q=1.6-1.9 l/sec.m., Km=144-321m^2/day.

The observation water level observation in well Q.8 gave the water level in the range 8.58-9.25m, ΔH_{max}=1.03m.

2.4 Middle-Upper Pleistocene impermeable layer ($Q_{II-III}hn_2$)

This is the upper deposit of Hanoi formation. This layer is not continuous and on the depth in the range 10-33.3m, in average 23.89m. This layer has its thickness thinner and thinner along the Red river, Damvac lake, Calo river, and especially along the Red river disappears and created so-called hydrogeological windows. This layer consists clayey sands, sandy clay and in some places silts with plant remaining. The average permeability is K_{evg}=4.33x10^{-4}cm/s. The thickness is in the limits 1.5-15.6m, average: 5.12m

2.5 Middle-Upper Pleistocene aquifer ($Q_{II-III}hn_1$)

This is the main aquifer in the study area. The aquifer consists of deposits of the lower part of the Red river formation, which is widely spreading and mostly covered by above deposits. This aquifer is exposed to the ground surface only in a small north west area of about 5km^2. This aquifer consists of gravels, grits, sands and clay, in some places with boulders concreted by clay and sandy clay. This aquifer consists mainly of gravels and grits with quartzite sands of grayish yellow and light grey color. Its depth and thickness increase northwards and northwestwards. Drilled wells usually met the aquifer at the depth 21-59.6m. Th thickness is from 3.1m to 23.7m, in average 13.01m. 36 pumping tests have shown Q=3.36-36.88l/sec, q=0.69-14.43l/sec.m, T=123-1643m^2/day, in average 749m^2/day, μ_{evg}=0.011

Water level observation data of aquifer $Q_{II-III}hn_1$ measured from 1992 to 1997 by the Vietnam North United Hydrogeological and Engineering Geological Company show: water level changes with seasons, the maximal magnitude ΔH_{max}=0.93-4.23m.

3. GROUNDWATER EXPLOITATION RESERVES EVALUATION

3.1 Present exploitation conditions

Groundwater has been exploited for water supply for Vinhyen town as follows:

Table 1. The present exploitation in Damvac well field

No.	Well	Pumping rate (m3/day)	Dynamic water level (m) (M.S.L.)
1	G3	1440	- 4.52
2	G5	1656	- 3.72
3	L7	0408	- 3.71
4	L8	1752	- 3.46

Hopthinh well field had one pumping well to serve Hopthinh concrete plant. This well is HT1. This well becomes out of order after some operation time. The recorded data show that the remaining pumping rate of the well 3000m^3/day.

3.2 Boundary conditions

3.2.1 *Upper Pleistocene aquifer ($Q_{III}vp_1$).*

This aquifer is directly lying on low permeable deposits on the east. This boundary can be considered as boundary type II with Q=const or Q=0 (this will be clarified during parameter identification). The Red river is flowing through west and south, however the river does not cut into the aquifer so along the river the condition type I or constant head condition for Holocene aquifer, but type III or general head condition (GHB) for the Upper Pleistocene aquifer.

Damvac lake is the inside aquifer boundary of also type III. In difference from the Red river, Damvac lake is directly located on the Upper Pleistocene aquifer ($Q_{III}vp_1$) so its vertical flow resistance is higher than that of the Red river.

The impermeable Middle-Upper Pleistocene (Q_{II-III}*hn2*) separates this aquifer with the Upper-Middle Pleistocene aquifer (Q_{II-III}*hn1*). Thus the boundary type is II (*Q*=0 or *Q*=const).

3.2.2 *Middle-Upper Pleistocene aquifer ($Q_{II-III}hn_1$).*

Bounding lines and boundary conditions are similar to Upper Pleistocene aquifer ($Q_{III}vp_1$), but with the difference in that it has an area of 5 km^2 exposed to the ground surface where the infiltration and evaporation may take place.

The leakage takes place from the upper aquifer or from Damvac lake via low permeable layers. Clay on the Damvac lake bottom has permeability 0.47m/day. Concerning the contact with Neogen formation underneath, the boundary can be assumed as type II (*Q*=0).

3.3 Proposed well locations.

Based on the water demand, the possible well capacity of 8 wells are proposed in Hopthinh wellfield (HT1, HT2, HT3, HT4, HT5, HT6, HT7 and HT8) and 7 wells in Damvac wellfield (G3, G5, L7, L8, G9, G10 and G11)(see fig. 2). By means of many alternatives of pumping scheme, following pumping scheme has been set up for exploitation:

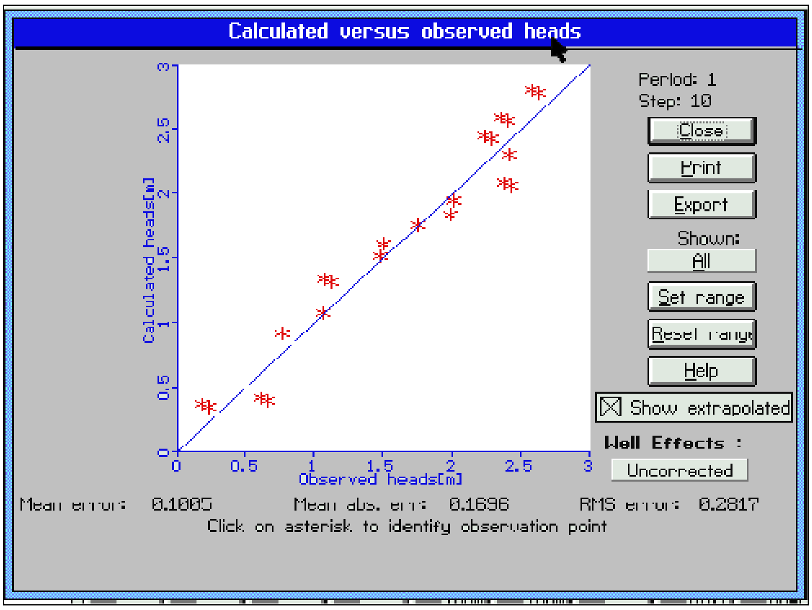

Fig.1 Graph of calculated and observed heads on the 7th of September 1998 (7/9/98).

HT1, HT2, HT3, HT4, HT5, HT6, HT7, HT8 planed pumping rate are 1000m^3/day per each and G7 is 408 m^3/day, G8 is 1656 m^3/day, G5 is 1752 m^3/day, G9 is 1000 m^3/day, G3 is 1440 m^3/day, G10 is 1000 m^3/day, G11 is 1000 m^3/day

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3.4 Calibration

After several 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 aquifer $Q_{II\text{-}III}$ hn_1 at the 7th of November 1998 (see fig. 1)

3.5 Results of prediction of exploitation pumping rates for Hopthinh and Damvac well fields.

The corrected model may predict the exploitation pumping rates of Hopthinh and Damvac well fields with total pumping time 27 years. The prediction periods are 5, 10, 15, 20, 25 and 27 years. Contour lines of water level at the end of project time are as follows:

Table 2. Prediction of dynamic water level (M.S.L)

Well	Pumping rate (m^3/day)	Estimated water levels (m) (M.S.L)						*H* Permissible (M.S.L)
		5 Years	10 Years	15 Years	20 Years	25 Years	27 Years	
HT8	1000	0.41	-0.20	-0.48	-0.65	-1.07	-1.08	-16.52
HT7	1000	-1.44	-2.07	-2.35	-2.51	-2.94	-2.95	-16.42
HT6	1000	-1.65	-2.28	-2.57	-2.74	-3.16	-3.17	-13.4
HT5	1000	-1.55	-2.20	-2.48	-2.65	-3.09	-3.09	11.3
HT4	1000	-1.62	-2.27	-2.56	-2.73	-3.16	-3.17	-9.3
HT3	1000	-1.62	-2.27	-2.56	-2.73	-3.17	-3.18	-11.99
HT2	1000	-1.10	-1.76	-2.04	-2.21	-2.66	-2.67	-13.01
HT1	1000	-1.34	-2.00	-2.29	-2.46	-2.91	-2.91	-14.82
L7	408	-4.75	-5.29	-5.58	-5.76	-5.93	-6.12	-12.1
L8	1656	-6.46	-6.99	-7.28	-7.47	-7.64	-7.85	-8.21
G5	1752	-4.33	-4.89	-5.17	-5.34	-5.52	-5.68	-10
G9	1000	-6.81	-7.33	-7.63	-7.81	-7.98	-8.20	-13.03
G3	1440	-4.82	-5.35	-5.63	-5.80	-5.96	-6.14	-7.34
G10	1000	-5.85	-6.36	-6.65	-6.83	-6.99	-7.20	-12.88
G11	1000	-6.88	-7.40	-7.73	-7.93	-8.10	-8.36	-15.30
Total	16256							

Table 3. Water budgets for Hopthinh and Damvac well fields

No.	Well field	Pumping (m3/day)	Water resources components in the pumping (after 27 years of exploitation)		
			Natural dynamic	Natural storage	Enforced dynamic
1	Hopthinh	8000	97%	3%	0%
2	Damvac	8256	56.8%	2.6%	40.6%

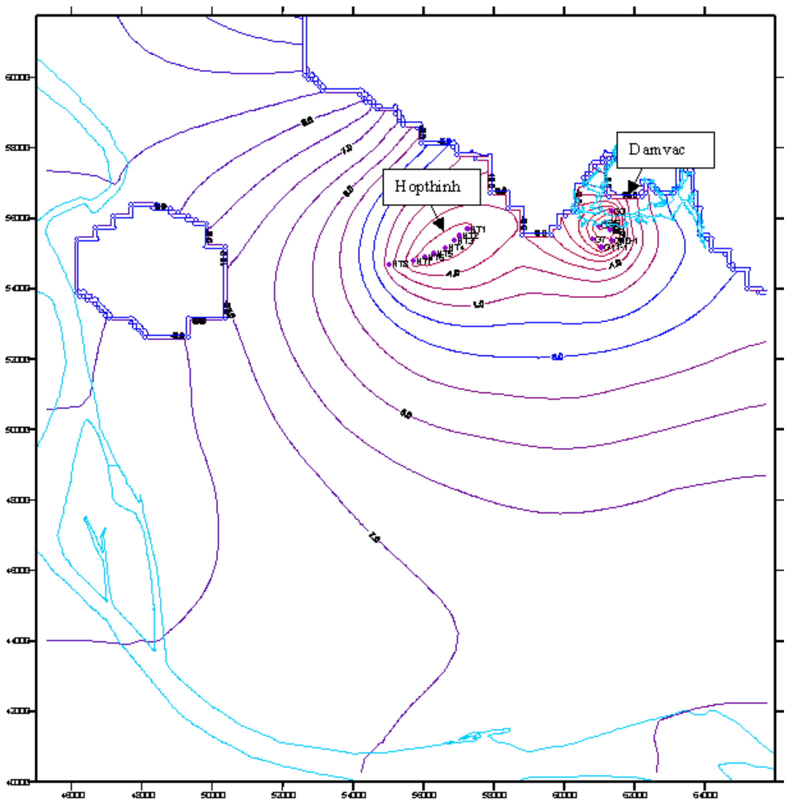

Fig. 2 Contour lines of water level of aquifer Q_{II-III} hn$_1$ at the end of project time

4. CONCLUSIONS

The following conclusions may be made based on the prediction of groundwater exploitation reserves 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 predict ground water exploitation reserves.

A result of prediction shows that the location of wells in Hopthinh and Damvac wellfield can meet the demand of 15000m^3/day for water supply and by the end of project time, dynamic water level is still higher permissible groundwater level for it's sustainable exploitation.

5. REFERENCES

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