II-155 A Practical Approach To Manage Groundwater in Drought Seasons

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1. Introduction. A concept on optimal groundwater utilisation and pumpage for promoting the groundwater conservation as well as measure for land subsidence in Japan has been investigated in real earnest from the end of the 1980s. A cabinet ministers' meeting on preventive measure for land subsidence (members of the meeting were nine ministers) held on November 1981 decided the guidelines of preventive measure for land subsidence at three basins: Nobi and Chikugo-Saga (1985) and Northern Kanto (1991).The priority policy of the guidelines is to develop new water resources in place of excessive groundwater use under an optimal groundwater pumpage. However, in recent decade the country met with serious water shortage on every three or four years. How to use groundwater resource in drought seasons becomes one of the important themes. There are different optimization methods in groundwater control. But, since the methods are difficult for non-professionals, from one side, and the application of the methods rarely gives a satisfactory results due to the inappropriate aquifer boundary conditions and parameters, from the other side. This paper has attempted to present an approach, which is practically simple to manage groundwater pumping with respect to the groundwater head constraints which can be specified on the land subsidence practice.

2. Numerical Scheme.

Aquifer. Suppose we have a confined aquifer as shown in Fig. 1. The top and left boundaries are prescribed flux q=0.0008 /(1m boundary length and $1m^2$/day transmissivity), e.g. , the prescribed inflow is Q=q.Δl.T, where Δl: boundary length (m), T: transmissivity (m^2/day). Right and bottom boundaries are constant head H=50.0m. The transmissivity zones are 16 and their distribution is shown in Fig. 1.

FEM model and pumping wells. The domain has been discretised into FEM mesh: 525 nodes and 480 square elements 200m by 200m and the modeled area is 4,800m by 4,000m (Fig. 1). Suppose that there are 95 pumping wells within the basin. The location of pumping wells, their chosen discharges and the steady state water level distribution is shown in Fig. 2. Those pumping discharges have been considered as the average ones. Let us divide the basin into four sub-domains as shown in Fig. 3. The total average pumping discharge of each domain is also indicated. Let us consider that we have the observation wells in the domains are: node No. 132 (sub-domain 1), node No. 144 (sub-domain 2), node No. 382 (sub-domain 3) and node No. 394 (sub-domain 4).

Generation of synthetic data. The relationship between the pumping change around its average value of each sub-domain and the water level fluctuation in all the sub-domains is to be analyzed. .Let the pumping discharges in sub-domain 2,3 and 4 remain unchanged, and equal to the above-mentioned average values. The pumping discharges of all wells in sub-domain 1 are subsequently taken equal to 60%, 70%, 80%, 90%, 100%, 110%, 120%, 130% and 140% of their above-mentioned average pumping values. Water levels at the observation nodes in the sub-domains are obtained by executing the FEM program for each case of these pumping discharge changes. Figure 4 presents the relationship between the pumping discharge change in sub-domain 1 and the water level in all sub-domains 1,2,3 and 4. This procedure has been repeated for other sub-domains 2,3 and 4. Respective relationships have been determined (not shown). The relations are all linear as the results show, and the linear relations are: $\boldsymbol{h} = \boldsymbol{a}(\Delta \boldsymbol{Q}) + \boldsymbol{b}$, where $\boldsymbol{h}$: water level, ΔQ: the change pumping discharge around its average value, $\boldsymbol{a}$ and $\boldsymbol{b}$ are some coefficients, and $\boldsymbol{b}$ corresponds to the average water level, e.g., in the case if pumping discharges remain as the average values. Let us denote the mean water levels in sub-domain 1,2,3 and 4 by $h_{1,mean}$, $h_{2,mean}$, $h_{3,mean}$, $h_{4,mean}$ respectively. The values of coefficient $\boldsymbol{a}$ have been evaluated and given in Table 1, and h_{mean} are given in Table 2.

Table 1. Values of coefficient $\boldsymbol{a}$.

By pumping change:	For sub-domain 1	For sub-domain 2	For sub-domain 3	For sub-domain 4
in sub-domain 1	-0.524×10^{-3}	-0.155×10^{-3}	-0.155×10^{-3}	-0.057×10^{-3}
in sub-domain 2	-0.166×10^{-3}	-0.216×10^{-3}	-0.057×10^{-3}	-0.053×10^{-3}
in sub-domain 3	-0.162×10^{-3}	-0.059×10^{-3}	-0.176×10^{-3}	-0.042×10^{-3}
in sub-domain 4	-0.053×10^{-3}	-0.045×10^{-3}	-0.029×10^{-3}	-0.109×10^{-3}

3. Solution for the pumping discharges. Suppose that the critical water levels in the sub-domains during drought seasons are given as $h_{1,cri}$, $h_{2,cri}$, $h_{3,cri}$, $h_{4,cri}$ for sub-domain 1,2,3 and 4 respectively. The pumping discharge changes (ΔQ) of the sub-domains can be determined by solving the following system of four equations (corresponding coefficients are from Table 1):

$$-10^{-3}\times(0.524\Delta Q_1 + 0.166\Delta Q_2 + 0.162\Delta Q_3 + 0.053\Delta Q_4) = h_{1,cri} - h_{1,mean}$$
$$-10^{-3}\times(0.155\Delta Q_1 + 0.216\Delta Q_2 + 0.059\Delta Q_3 + 0.045\Delta Q_4) = h_{2,cri} - h_{2,mean}$$
$$-10^{-3}\times(0.155\Delta Q_1 + 0.057\Delta Q_2 + 0.176\Delta Q_3 + 0.029\Delta Q_4) = h_{3,cri} - h_{3,mean}$$
$$-10^{-3}\times(0.057\Delta Q_1 + 0.053\Delta Q_2 + 0.042\Delta Q_3 + 0.109\Delta Q_4) = h_{4,cri} - h_{4,mean}$$

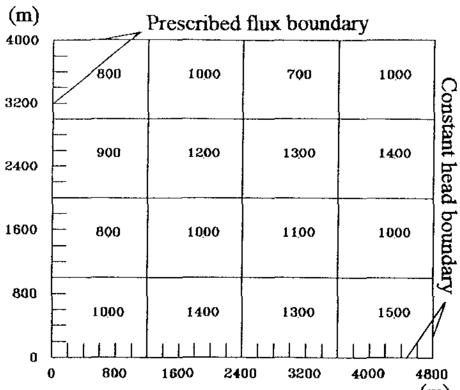

Fig. 1. Aquifer boundary conditions and transmissivity (m^2/day) zones.

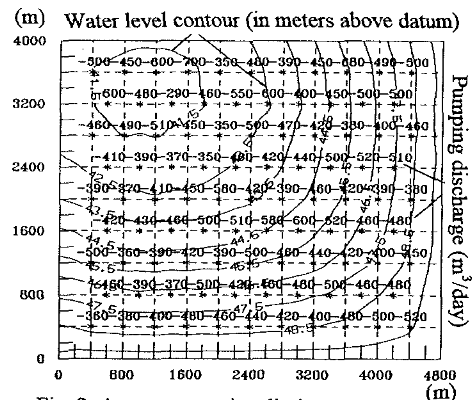

Fig. 2. Average pumping dischagres and water level distribution.

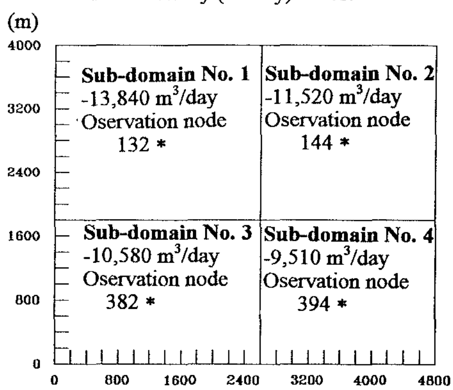

Fig. 3. Sub-domains and their average pumping discharges.

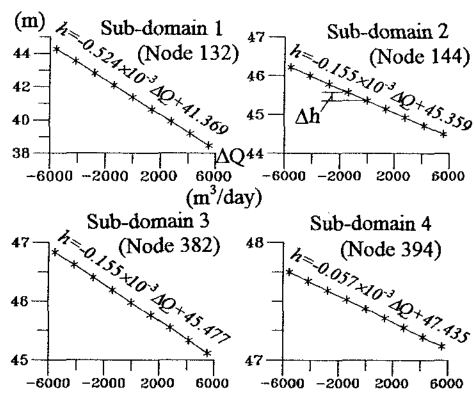

Fig. 4. Water level fluctuation caused by the pumping discharge change in sub-domain 1.

Let us assume some critical head values and estimate the pumping discharge changes and then use the newly estimated pumping discharges in the finite element simulation to calculate the head (which we call the true head values h_{true}). The results are shown in Table 2.

Table 2. Calculated results.

Sub-domain	h_{mean} (m)	$\Delta h = h_{cri} - h_{mean}$	ΔQ (m^3/day)	h_{cri} (m)	h_{true}(m)	$\Delta h = h_{cri} - h_{mean}$	ΔQ (m^3/day)	h_{cri}(m)	h_{true}(m)
1	41.369	4.0	2425.0	37.369	37.191	8.0	5046.0	33.191	33.118
2	45.359	3.0	9510.0	42.359	42.249	6.0	20803.0	39.249	39.204
3	45.977	2.0	5180.0	43.977	43.877	4.0	11345.0	41.877	41.886
4	47.435	1.5	5873.0	45.935	45.847	2.0	1223.0	45.547	45.375

4. Discussion. From the result we can see that the difference between the simulated head (true head) and critical head is insignificant. Since the land subsidence is proportional to the water level drop, the introduced approach may be applied to practical problems. From the above illustrating example, the water level drop is proportional to the pumping discharge (if the recharge or discharge scheme, the aquifer boundary conditions and parametrs etc. are constant). Therefore, the above approach can be used to determine the additional pumping discharge in the drought seasons based on the allowable land subsidence values. The latter is often expressed in term of water level drop or water level. The authors suggest that the groundwater practitioners check the validity of this approach for concrete their study fields which have different shapes and sizes of the sub-domains, which often represent the administrative regions, aquifer size, boundary conditions, aquifer parameters, pumping scheme etc. before actual application.

Reference. Kuniaki Sato and Nguyen Van Hoang, 1995, Recent countermeasures for land subsidence and groundwater resources in Japan. *Proceedings of the Fifth International Symposium on Land Subsidence, The Hague, October 1995. IAHS Publ. no. 234, 1995*, pp. 471~479.