Simulation Analysis of 3D Seepage Groundwater Flow and Making of 3D Geological Structure Model in Multilayered Ground(Post-Print version)

著者	Yamamoto Takuya, Kitaoka Takahumi, Kusumi Harushige
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Simulation Analysis of 3D Seepage Groundwater Flow and Making of 3D Geological Structure Model in Multilayered Ground

Takuya Yamamoto [1], Takahumi Kitaoka [2], and Harushige Kusumi [3]

[1] Graduate school of Science and Engineering, Kansai University, Osaka JAPAN
E-mail : k071598@kansai-u.ac.jp
[2] Graduate school of Science and Engineering, Kansai University, Osaka JAPAN
E-mail : k111781@kansai-u.ac.jp
[3] President, Kansai University, Osaka JAPAN
E-mail : kusumi@ipcku.kansai-u.ac.jp

In the management and a usage of a groundwater resource, we need to work on an accurate grasp of the current situation and to make a future vision in the region where the groundwater exploitation is active. In this research, we aim at the creation of the three-dimensional geological structure model in multilayered ground and the three-dimensional seepage flow analysis of groundwater by using the model. The area in this research exist many multi-layers which are alternately stratified gravel layers and clay layers. Firstly, based on bowling log and an altitude distribution map, we grasped the topography and the geological structure of a target area. Secondly, based on boring log, we interpolated the layer thickness of every layer in a model by using the Kriging method. The outline of the three-dimensional geological structure is completed by piling them up. Thirdly, considering of the position of pumping wells and the layer thickness distribution, we divided mesh. Finally, we reproduced groundwater flow by conducting groundwater analysis, and created the figure which visualized the groundwater flow.

1. INTRODUCTION

Fushimi's groundwater has long supported Kyoto's traditional industries. This area has a plentiful supply of good quality groundwater suited to making Japanese sake. The object area, which is 4 km2 and overcrowded with 50 wells, uses groundwater. However, planned groundwater use for protecting groundwater resources is not performed. In the management and usage of groundwater resource, we need to work on an accurate grasp of the current situation and to make a future vision. If an excessive pumping is continued, it can cause the exhaustions of groundwater and subsidence. It takes 1400 years for groundwater to recover the original resources, and 16 days for rivers. Therefore, it is required to make a sustainable method for the use of groundwater that takes surrounding environment into consideration.

In this study, we examined the influence that pumping had on the groundwater flow in the area where many discharge wells were crowded based on the results of a 3D seepage flow analysis. In addition, we made the geological structured model that reproduced the region to obtain a good result of the accuracy.

2. GEOLOGICAL CONDITIONS

Fig.1 shows the topographical map of the surrounding examined region.

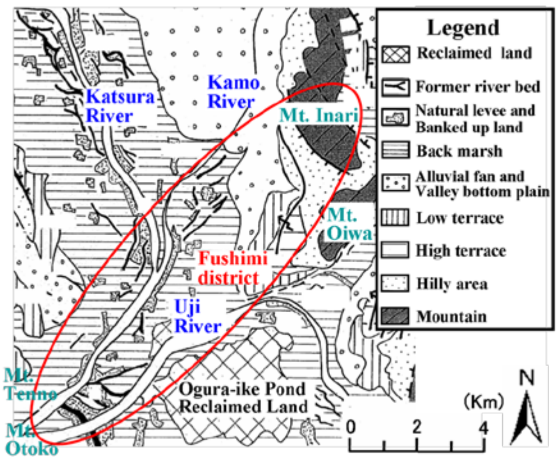

Figure 1 Topographical map of Kyoto

Fushimi-Ward, Kyoto-city is an area belonging to the Kyoto Basin known as having abundant groundwater resources. Fushimi Ward located in the south of Kyoto City is composed of the plain part along three rivers, Katsura river, Kamogawa river, Uzi river, and the mounting level of the Higashiyama mountain range the Momoyama hill that runs are making a south end. Fig.2 shows the geologic profile. As for the geological features composition in the analytical object region, there is a diluvial layer that is the laminated ground of gravel, sand, and clay and the alluvial layer coats this to the place by about 5m. The structure of the alternated layer ground is complicated. The layers from which 16 differs overlap in the range of 180-m depth can be grasped

3. GROUNDWATER PROPERTY

Fig.3 shows the location of monitoring wells and geological profile (the expansion of the area around Fushimi Brewery companies). We set up 23 monitoring wells in this area. In this area, there are about 50 pumping wells providing water for sake-making. Fig.4 shows the temporal change of the confined groundwater level and pumping discharge. As shown in Fig.4, it turns out that the groundwater level is influenced by pumping.

4. MAKING OF 3D MODEL

(1) Area of analysis

Fig.5 shows the range of modeling that is the object region in the present study. The analysis range like figure was decided from the area of about 9000m for the east and west direction about 9500m and the south north. The boundary of the model is watershed and a river boundary. The bottom of a model is a bedrock. The deepest length from ground level to a basement rock is about 800 m in depth.

(2) Modeling

It is difficult to completely grasp all geological structure because there is little number of geological data. Fig.6 shows the layer thickness data of A layer. Layer thickness data of Fig.6 are data estimated by using the Kriging method that is space interpolation. We grasped all the geological structure in the object region in this way. And we made the 3D geological structure model that reflected the geological structure that we estimated. Fig.7 shows the 3D model. A perpendicular direction is displayed at 3 times magnification.

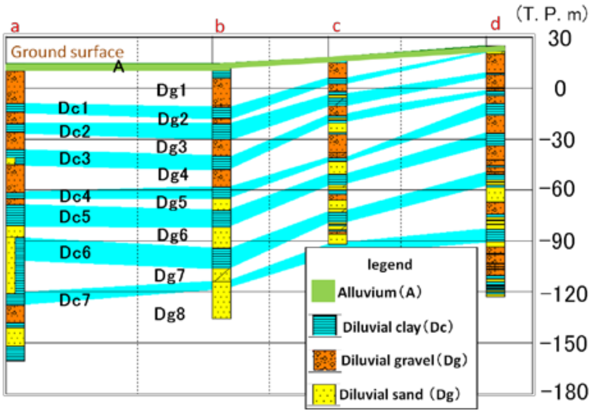

Figure 2 Geologic profile

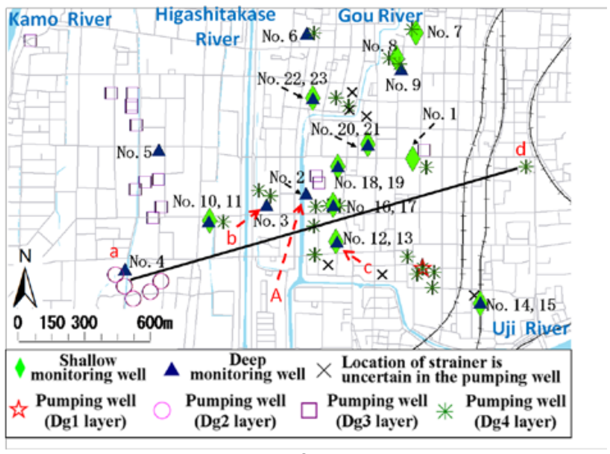

Figure 3 Location of monitoring wells and geological profile

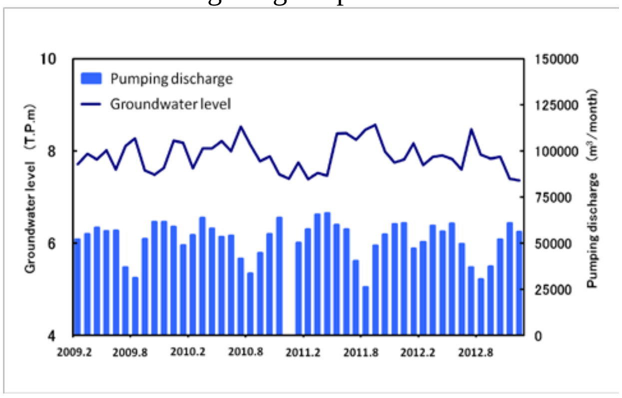

Figure 4 The water level of No.5 and the pumping discharge from Dg3 layer

(3) Mesh partition

In horizontal direction, we cut most of the meshes in detail to examine influences on groundwater level. This was also done to check the mechanism of groundwater level around pumping well. The number of nodes of analytical meshes is 47,520 and the number of elements is 89,001.

5. SEEPAGE ANALYSIS

In 3D seepage flow analysis in the present study, AC-UNSAF3D by the finite element method was used. This time, we carried out the only steady state analysis. And the influence of pumping on groundwater flow reproduced the largest state.

First, we analyzed with no consideration for pumping. The water level contour chart was made from the result of obtaining by these underground water heads, and a rough flow was forecast. In addition, the underground water head obtained by the analytical result and observed underground water head are compared, and the validity of the made stratum model is examined.

Next, we analyzed with consideration for pumping. And we compared the second result with the first result. In addition, we assessed the influence of pumping on groundwater flow.

6. GROUNDWATER FLOW OF NATURALL STATE

(1) Boundary condition

We set boundary condition in a river, a watershed, bedrock, hilly area. In the river, we set a prescribed head boundary of the ground level nodes. The watershed and bedrock, we set an impermeable boundary at the all nodes that composed it. Hilly area, we set rainfall infiltration boundary. In general, it is said that the amount of recharge of groundwater was about 29-33% of the rainfall. For this reason, the amount of recharge of groundwater is set at 30%.

(2) Ground physicality parameter

Table 1 shows the ground physicality parameter. The ground physicality parameter set up the parameter with compatibility with an observation water level using examples from reference

(3) Result

Using the analytical result, the hydraulic contour chart indicated by the colors and the one drawn by the contour line are shown in the Fig.8. Fig.8 shows the groundwater flows toward the part where three rivers in the southwest are joined from the hill part in the northeast.

The number that comparative analysis of the observation data and the analysis result is 23. Table 2 shows comparative analysis data. The mean squared error is 0.97m, and the median of error is 0.57m. Overall, the analysis result higher than an observation water level was obtained. However, since the observed water level is also changed around 1 m at every year, the error of an analysis result is a permissible range. Therefore, it can be estimated that this model can be reproducing the groundwater flow of a natural state.

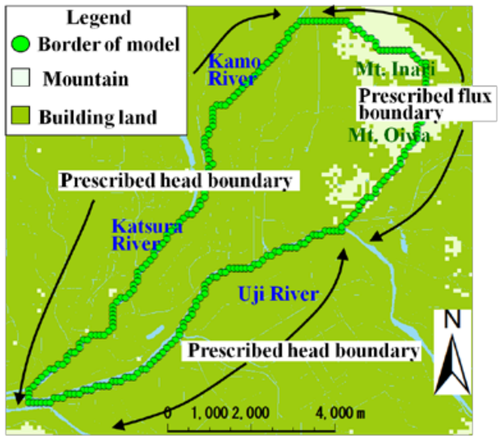

Figure 5 Boundary conditions of wide-ranged analytical model

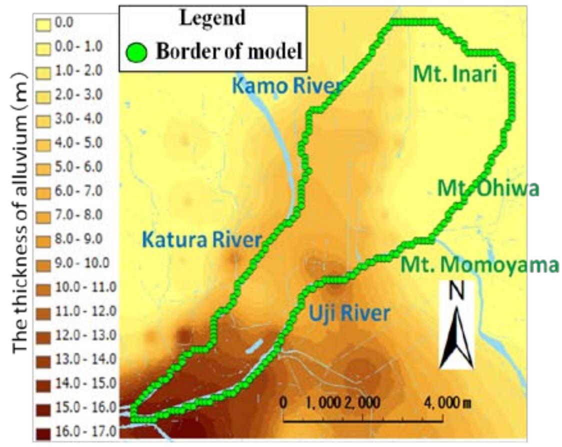

Figure 6 The thickness of alluvium are obtained by Kriging method

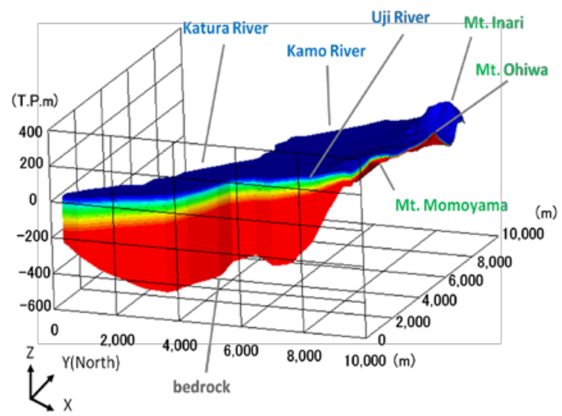

Figure 7 3D geological structure model

Table 1 The ground physicality parameter

	Coefficient of permeability X Y (cm/s)	Coefficient of permeability Z (cm/s)	Specific storage (1/m)	Effective porosity (%)
A	5.0×10^{-2}	1.0×10^{-2}	2.0×10^{-3}	20
Dg(1~8)	5.0×10^{-2}	1.0×10^{-2}	2.0×10^{-3}	20
Dc(1~7)	5.0×10^{-6}	1.0×10^{-6}	1.2×10^{-4}	10
Hill are	1.0×10^{-3}	5.0×10^{-4}	2.0×10^{-3}	20

7. AREA OF INFLUENCE

(1) Boundary condition

A river boundary, a watershed, a basement rock, and rainfall infiltration boundary are the same conditions as previously. In addition, we set up the pump discharge as a flow boundary condition. The pump discharge was set as the node corresponding to the place of a strainer. The number of discharges wells is 44.

(2) Ground physicality parameter

Ground physicality parameter is the same as last time.

(3) Result

Fig.9 shows the graph which compares two analysis results. Two results are a water level in consideration of pumping, and a water level which is not taking pumping into consideration. Fig.10 shows the line which connected the point which compared the analysis result. The line shown in Fig.10 corresponds to the X-axis of Fig.9. The point A shows the center of the area that pumping is performed.

As shown in Fig.9, in the pumping well crowd area outskirts, the water level is descending. The amount of lowered water level in A point is 0.55 m. Aroud point A, the amount of lowered water level is decreasing gradually. The lowered water level of the southwest are less than the lowered water level of the northeast. The amount of lowered water level of the point northeast separated from A point 1.5 km is 0.35 m. In the direction of southwest, it is 1.4 m. This reason is considered that the supply of the flow from a river is large compared with the direction of northeast.

8. CONCLUSIONS

In this research, we analyzed to examine how the pumping wells influence groundwater behavior. The 3D geological structure model that we made represents the topography of the area for exactly. The groundwater flow of a natural state was reproduced in the seepage analysis with no consideration for pumping. In addition, we examined the influence of pumping on groundwater flow by setting up the pumping discharge. As a result, we were able to presume the area of influence and the amount of lowered water level. We would like to carry out transient analysis and to presume temporal spread of the area of influence from now on.

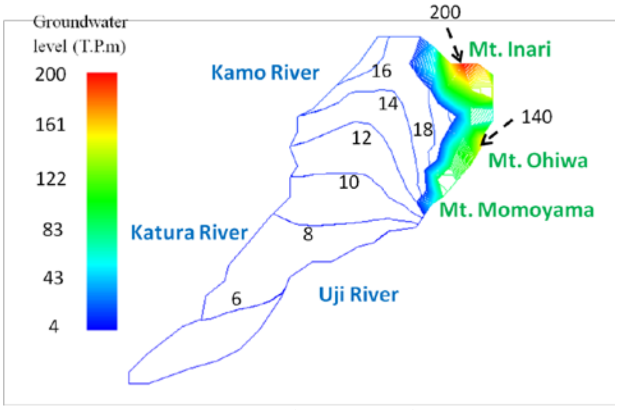

Figure 8 Results of seepage flow analysisl

Table 2 Static score of analysis (m)

MSE	MEDIAN	ERORR(MAX)	ERORR(MIN)
0.97	0.57	2.82	0.04

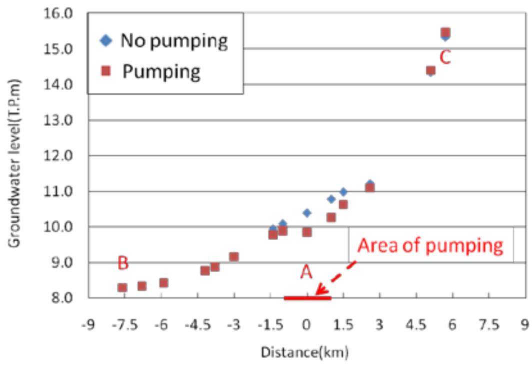

Figure 9 Influence of pumping

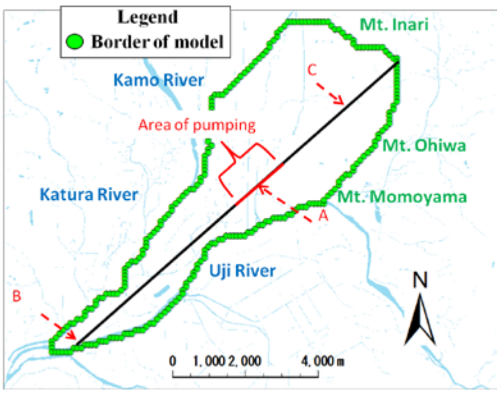

Figure 10 The X-axis of Fig. 9

REFERENCE

Kitaoka, T., Nakamura, M., Kusumi, H. (2011): Establishing a 3D model of groundwater advection and diffusion at Fushimi ward in Kyoto basin Japan, Proc. of EIT-JSCE Symposium 2011 on Human Security Engineering.