The effect of induced recharge from Shinano River to the subsurface environment such as subsurface temperature, environmental isotopes and chemical components of groundwater

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Abstract: The recently measured subsurface temperature data (2000-2002) of this study were compared with that measured in the same wells during the period 1977-1983 (Taniguchi, 1986). As a result of correlating the old profiles with the new ones, three groups of wells could be distinguished. These phenomena were caused by the change of groundwater flow due to pumping and surface warming due to urbanization.

Key words: temperature profile in a borehole, pumping for melting snow, subsurface temperature, induced recharge

Introduction

Nagaoka Basin is located in the south of the Niigata Plain along the coast of Japan Sea, Honshu, Japan. The major geological structure of the Nagaoka Blain was formed by a series of crustal movements; which occurred from the Late Pliocene in the Pleistocene epochs. The surrounding hills (up to 2000 m a.s.l.) consist of thick sedimentary rocks of the Plio-Pleistocene Period, which forms the basement of the major aquifers of the plain. The land cover of the plain is dominantly occupied by urban and paddy field areas whereas that of the surrounding hills are of forests (Fig. 1). According to the borehole records and aquifer test data, one major aquifer consists of four formations (I-IV) is distinguished in this groundwater basin (Nagaoka construction office, 1975). Main hydraulic conductivities of these formations (which are identified as layers I, II, III and IV) are 0.12, 0.092, 0.022 and 0.018 cm/s respectively in descending order (Nagaoka construction office, 1975).

According to Taniguchi (1986), The Shinano River is naturally a gaining stream fed from the groundwater all through the reach in Nagaoka area except during winter season. He also had observed that during the winter the water table at the center of the city drops to a level lower than the water level of Shinano River owing to heavy pumping of the groundwater used for snow melting. This kind of water table decline has strongly leaded to artificial seepage from the river into the groundwater (Kayane et al., 1985). The recovery of the water table was found to be very rapid during April. In the present study, groundwater table changes were checked in December, June and March. Compared to the observations made by Taniguchi (1986) the recovery rate has been diminished drastically and it is expected to recover fully either during July or August.

Scientific paper

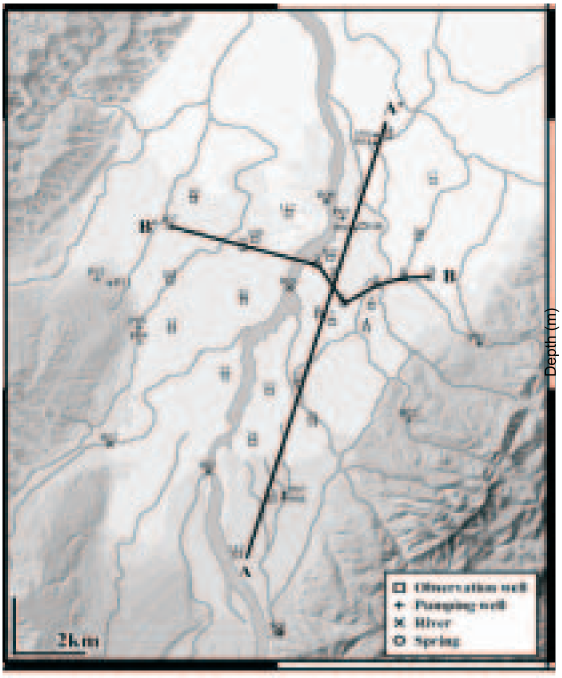

Fig.1 Location of wells and cross section lines

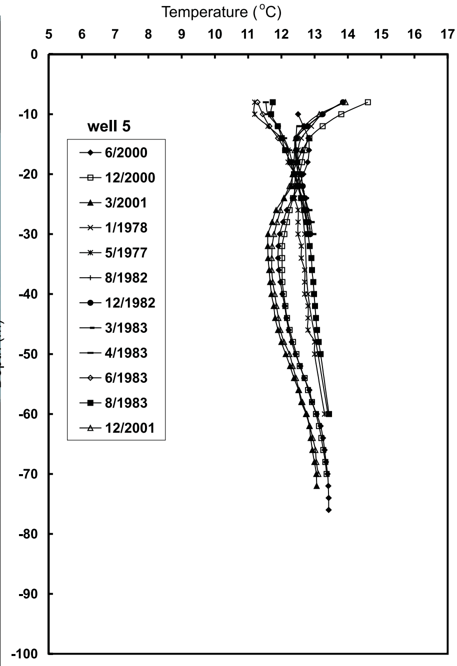

Figure 2. Temperature profile in the well5.

The Shinano River has been subjected to continuing hydrological changes and became as a potential recharging source for the groundwater in the urban area almost all through the year, which may seriously affect the subsurface environment of the urban area. The vertical two-dimensional distribution of the hydraulic heads along the line B-B' is shown in Figs. 3. In December the water flows with moderately low rate from south to north with a gentle slope. In March, the water table drops down with steep slopes under the urban area and causing the groundwater flows from different directions towards the urban area. After March

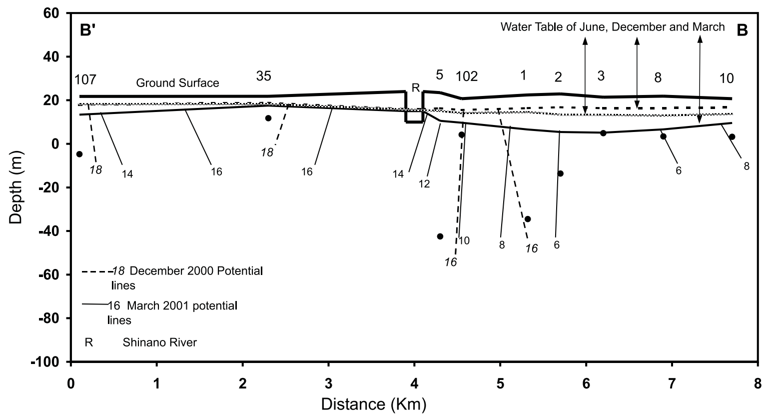

Figure 3. Vertical two-dimensional distribution of hydraulic heads along the line B-B'.

the water table starts to recover as shown in the diagram (Fig. 3), it does not recover till June and it is expected to reach the normal condition by July or August.

Subsurface temperature distribution

Subsurface thermal measurements were generally made in observation wells, which are assumed to be in equilibrated thermal state between water and the surrounding solid material. Temperature measurements were carried out in 30 observation wells (20 to 115 m depth). The equipment used for the measurements was a sophisticated digital thermister thermometer (resolution of 0.01°C) attached to a cable of 300 m length. Data were recorded from the water table till the bottom of the hole every two meter interval in the downward direction.

The recently measured subsurface temperature profiles of the period from 2000 to 2001 were compared with that measured in the same wells during the period from 1977 to 1983 (Taniguchi, 1986). As a result of this comparison, three groups of wells could be distinguished. The first group locates in the urban area and shows a significant temperature increase in the wells of 1, 2, 3, 4, 6, 7, 8, 20, 33, and 34. The warming effect reaches its maximum depth (around 60 m depth) in the areas of wells 1and 2 and it is expected to be shallower in the surrounding areas. The average increase in the subsurface temperature at the water table ranges from 1 to 3 °C; such range may be in correlation with the intensity of the urbanization. The subsurface temperature increase reaches its maximum value in the shallow zones under the center of the urban area and its minimum in the areas around Nagaoka City.

The second group of wells includes well 5 (Fig. 2) and shows a subsurface temperature decrease. Well 5 temperature profile shows two significant phenomena. 1) temperature decreases in its middle part (from 22 to 60 m depth) by about 1.5 °C, and 2) changing the temperature profile from discharge type into recharge type. These two phenomena are occurred as a result of the sever pumping during the last 40 years, where Shinano River have been changed from gaining to losing stream under the effect of sever pumping during the last 40 years. The third group of wells mostly locates in the cultivated area and includes wells 10, 11, 17, 19, 25, 26 and 36, which do not show marked temperature changes. As a result of classification, all the wells, which have temperature increasing trend are located in the main urban area and that have no changes are located in the paddy fields as well as the rural areas. Well 5 is located in the main urban area close to the Shinano River (in a distance about 150 m).

The effect of Shinano River on the subsurface temperature is clearly shown as in Fig.4. A cold zone of less than 12.0 °C occurs under the Shinano River. This phenomenon could be explained as a result of induced recharge from Shinano River under the effect of groundwater pumping during the last 40 years in the urban area.

CONCLUSIONS

The surface warming (both urban and global warming) as indicated from increasing the air temperature by about 0.056 °C/year during the last 24 years was revealed from the subsurface temperature data. This phenomenon could be obtained from, 1) subsurface temperature history in the urban area, which shows increasing trend, and 2) existence of warm zone under the urban area, which means that temperature increases is related to a surface warming.
As a result of the sever pumping in the urban area during the last 40 years, Shinano River has been changed from gaining to losing stream in that area. This phenomenon was suggested by the decrease in the recently measured subsurface temperature data in the middle part of well 5 (from 22 to 60 m depth from the surface) by about 1.5 °C compared with that measured by TANIGUCHI (1986) about 20 years ago. In contrast to the urban area, the subsurface temperature history of the cultivated land and the rural areas does not show any significant temperature changes, this is due to the absence of the urban warming.

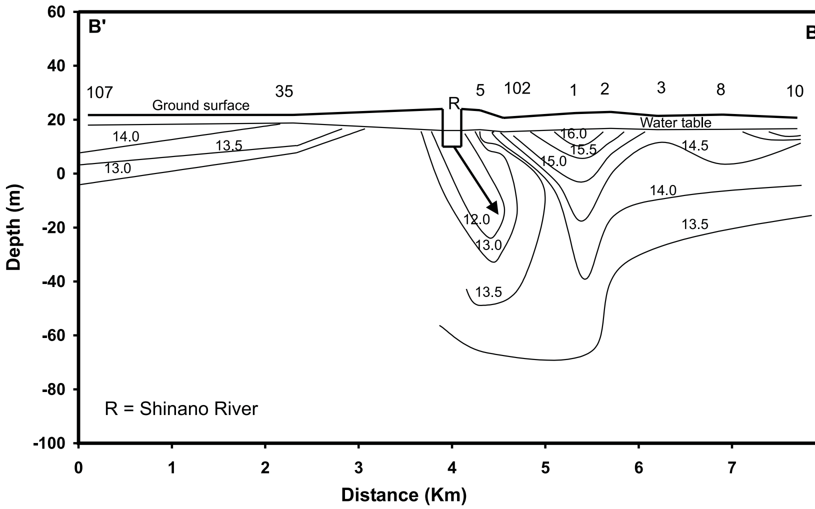

Figure 4. Vertical two-dimensional distribution of subsurface temperature in Dec., 2000.

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