Underground temperature change in the alluvial fan of the Nagara River, central Japan

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Generally, the underground temperature is constant except near-surface. The temperature in the near-surface (e.g. above 10 m depth) is annually changed due to the effect of seasonal change of ground surface temperature. As the thermal conductivity of rocks and soils are quite low, this seasonal change of ground temperature cannot reach below a certain depth. This depth is dependent on not only the thermal conductivity of rocks or soils but also the groundwater flow in a vertical direction. The constant temperature in a certain depth is almost consistent with the average of ground surface temperature. Low temperature geothermal uses such as ground-coupled heat pumps and groundwater heat pumps apply the temperature difference between surface and underground to the thermal energy use. As the underground temperature is constant, the underground becomes a heat source in winter and a heat sink in summer. Alluvial fans are recharge areas of groundwater and that rapid groundwater flow are expected. In this study, we clarify the distribution of the underground temperature in an alluvial fan to understand the potential of low temperature geothermal energy.
Study area is an alluvial fan of the Nagara River, central Japan. This alluvial fan is located in the marginal area of the Nobi plain. The underground of this alluvial fan mostly consists of sands and gravels and often intercalate thin fine sand and silt layers. The aquifers are divided by these sand and silt layers. The underground temperature of this area had been measured from May 2013 to May 2014 and from April 2016 to February 2017. The temperature is measured in boreholes with the length of 30 m. The measurement is performed once a month by a thermistor thermometer with the interval of 1 m depth. Ground temperature change in each depth of each well is well fitted by a sine curve. Average temperature, phase difference and amplitude of the temperature change in each depth of each well are calculated from the fitted sine curves. The results of underground temperature measurements show that the temperature profiles of most wells can be divided into two zones; the shallower apparent thermal conductive zone and the deeper thermal convective zone. The former is characterized by the decrease of amplitude toward downward, while the latter is almost constant temperature in the zone.
The thermal diffusivity is calculated from the temperature profiles of the shallower apparent thermal conductive zone. The distribution of the calculated thermal diffusivity is characterized by the lower values in the middle part of the fan and the higher in the marginal part. The thermal diffusivity cannot be calculated near the apex of the fan due to almost no shallower apparent thermal conductive zone. The values between the middle and marginal parts are greatly different. This suggests that the difference of the value results not from the thermal property of the formations but from the vertical velocity of the groundwater flow. The ground surface in the middle part is mostly covered by a silt layer and this would prevent water infiltration from the surface.
The temperature distribution in the deeper thermal convective zone is as follow. Phase difference of ground temperature against the river temperature basically increases from north to south in the southern side of the river. Although some wells far from the river seem to be out of sequence, the travel times of the groundwater from the river to these wells would be more than 1 year. The value of the phase differences of these wells should be added 1 or 2 years. The phase differences in the northern side of the river show different and complicated characteristics relative to the southern side. This suggests that the groundwater flow along the old river channels and from the tributary river plays an important role in the underground temperature distribution of the northern side. The distribution of the annual average temperature shows

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that the wells near the river are lower temperature. The average temperature of the river water is lower than the average air temperature of study area. These lines of evidence suggest that the area near the river is the recharge area.
For the low temperature geothermal use, the natural change of the underground temperature is important for the efficiency of the heat pumps. The area where the phase difference is 6 months is the best, because the efficiency of the heat pumps becomes higher when the temperature of the heat source is lower during cooing and higher during heating. The potential study of the low temperature geothermal uses should contain the annual temperature change in the alluvial fans.

Keywords: underground temperature change, alluvial fan, Nagara River

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