GSHP studies under CCOP Groundwater Project

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19th October, 2014
Groundwater Flow System

Potential distribution on the surface of the theoretical flow region

Topographic elevation above standard datum in feet

Equipotential line

Regional System

Intermediate System

Local System

valley bottom

Watershed

Stagnant water

Equipotential line

Line of groundwater flow (Toth, 1963)
Groundwater Flow System and Subsurface Thermal Regime

(a) static groundwater
\[ \frac{\partial h}{\partial x} = 0, \quad \frac{\partial h}{\partial z} = 0, \quad \nabla v = 0 \]

(b) thermal regime under condition of (a)
\[ \frac{\partial T}{\partial x} = 0, \quad \frac{\partial T}{\partial z} = G, \quad T = T_s, \quad \nabla^2 T = 0 \]

(c) simple regional groundwater flow system
\[ \frac{\partial h}{\partial x} = 0, \quad \frac{\partial h}{\partial z} = 0, \quad \nabla v = 0 \]

(d) thermal regime under condition of (c)
\[ \frac{\partial T}{\partial x} = 0, \quad \frac{\partial T}{\partial z} = G, \quad \nabla^2 T - v \nabla T = 0 \]

h: hydraulic head,
v: groundwater flow velocity,
T: subsurface temperature,
T_s: constant surface temperature,
G: constant temperature gradient,
x,z: coordinate

(modified from Domenico and Palciauskas, 1973)
Measurement of Subsurface Temperature

Thermometer
(Digital thermistor)

Observation well
(Monitoring for groundwater level and land subsidence)
Distribution maps of Subsurface Temperature

Subsurface temperature distribution at 50m depth from surface in Yamagata Basin

Subsurface temperature distribution at 100m depth from surface in Nobi Plain
CCOP
Coordinating Committee for Geoscience Programmes in East and Southeast Asia

Mission: Facilitate & coordinate the implementation of applied geoscience programmes
Contribution to economic development and improvement of the quality of life

13 Member Countries: Cambodia, China, Indonesia, Japan, Korea, Lao PDR, Malaysia, Papua New Guinea, Philippines, Singapore, Thailand, Timor-Leste and Vietnam

14 Cooperating Countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Netherlands, Norway, Poland, Russian Federation, Sweden, UK and USA
CCOP Groundwater Projects

Involvement of Geological Survey of Japan, AIST in the project
Phase I (2005 ~ 2008)
Phase II (2009 ~ 2013)

CCOP-GSJ/AIST Groundwater Project Phase II (2009 ~ 2013)

- Main theme in this project is “Renewal of database for the Hydro-geological map in CCOP regions”
- To construct database and its design
- To compile data of Chao-Phraya Plain, Thailand and Red River Delta, Vietnam
- To make an Asian Standard of the Hydro-geological map
Measurement of hydraulic potential and groundwater temperature at observation well in Thailand
Sampling of river water for chemical analysis

Survey members
Subsurface Temperature Gradient in the Chao Phraya Plain, Thailand
Design of CCOP Hydro-Geological Map

- GW data of Chao Phraya Plain in Thailand, and Red River Delta in Vietnam are compiled
- By clicking country name on starting page, data area is displayed
Magnified view around Thailand
By clicking “Thailand”, map of Chao-Phraya Plain is displayed
Hydro-geological database of Chao Phraya Plain
By clicking on observation point, observation data is displayed
Observation data includes well information (location, well depth, screen depth), EC, pH, isotopes etc., groundwater quality plotted by stiff diagram and groundwater temperature.
List of Hydro-geological data

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December, 2005
Outcomes of Groundwater Phase II

CCOP Project Report

- GW-1 : FY2009 Bangkok meeting
- GW-2 : FY2010 Xian meeting
- GW-3 : FY2012 Hanoi meeting
- GW-4 : FY2013 Bandung meeting

CCOP Groundwater DB

- Chao Phraya Plain, Thailand
  (76 points, 186 samples)
- Red River Delta, Vietnam
  (63 points, 254 samples)
- Other areas (by Excel Format)
CCOP Groundwater Sub-Project

• New sub-project under CCOP GW Project using CCOP GW DB started from April 2013
• Title of the sub-project is “Development of Renewable Energy for Ground-Source Heat Pump System in CCOP Regions”
• Chulalongkorn University (Thailand), Akita University (Japan) and GSJ have cooperation program under the CCOP sub-project and installed GSHP System on premise of Chulalongkorn University
Objectives of this sub-project are;

- To demonstrate GSHP system in Bangkok City, Thailand
- To find out adjustment and modifications needed for GSHP system in tropical region
- To develop suitable maps for GSHP system in Thailand reflecting large-scale groundwater flow/heat transport model
Atmospheric and subsurface temperature variation at different climatic regions

Is GSHP applicable everywhere? Not really in tropics…

Ref: Yasukawa et al., 2009

Monthly mean atmospheric and subsurface temperature
Can we use GSHP System in tropics?

- In East-Asia, where significant economical growth in this century is expected, energy saving and environmental protection are major matters of importance.
- Promotion of GSHP may contribute to energy (electricity) savings and protection of the environment.
- However, in tropics where space-cooling is needed, subsurface temperature is generally higher throughout a year and the underground is not suitable for heat exchange.
- Nevertheless in tropical regions, underground may be used as a cold source, if there exist seasonal and areal variation in atmospheric temperature, and subsurface temperature is rather low.
Shallow subsurface temperature affected by groundwater flow

- At recharge zones (high elevation), shallow temperature is lower, while it is higher at discharge zones.
- At recharge zones, underground may be used as cold source in tropics.

Subsurface temperature profile with groundwater flow.
Temperature measurements in Thailand

Department of Groundwater Resources of Thailand
Subsurface Temperature Profiles

Ref: Yasukawa et al., 2009
Merit for cooling
Comparison between subsurface and atmospheric temperature

Subsurface temp (0-50m)
Atmospheric monthly mean max.
Atmospheric monthly mean min.
Atmospheric annual mean

Ref: Yasukawa et al., 2009
Temperature measurements in Vietnam

Observation wells and measured temperature at a depth of 50 m
Merit for cooling
Comparison between subsurface and atmospheric temperature in Hanoi

Ref: Yasukawa et al., 2009
Construction of GSHP System in Chulalongkorn University

Guest house in Chulalongkorn Univ.
Continued

Drilling for installation of heat exchanger
After installation of heat exchange pipe
Continued

Ductwork from borehole to guest house

GSHP and cooling fan
Continued
Conclusions

Temperature observation results in Thailand and Vietnam show possibility of GSHP application for space cooling at places where subsurface temperature becomes lower than atmospheric temperature in some season.

Hanoi, Vietnam is not a tropical region. However, the observation results would be valuable as base data for potential resource mapping. GSHP as heating system may also be useful for drying in humid winter season in Hanoi. Thus, new application of GSHP may be found through climatic and subsurface data.

System performance depends not only on subsurface temperature but also on the operation plans and subsurface thermal parameters. Nevertheless, our temperature data will be essential as base data for GSHP promotion.
Thank you for your kind attention