31st WEDC International Conference, Kampala, Uganda, 2005

MAXIMIZING THE BENEFITS FROM WATER AND ENVIRONMENTAL SANITATION

Groundwater management using groundwater modeling: Case study on Akaki Wellfield; Addis Ababa City, Ethiopia

Shiferaw Lulu, Abebe G/Hiwot, Kebede Tsehayu and Solomon Waltanigus, Ethiopia

Groundwater Modeling is one of the main tools used in the hydrogeological sciences for the assessment of the resource potential and prediction of future impact under different circumstances/stresses. Its predictive capacity makes it the most useful tool for planning, design, implementation and management of the groundwater resources. Although it has been widely used by developed countries since the 1970's, its importance and application was not well understood in Ethiopia until the 1990's. Some fragmental works to solve specific problem are appearing in recent times. One of such works is the groundwater modeling work on Akaki Wellfield, which is a wellfield developed for the supply of Addis Ababa City. Groundwater model has been developed for Akaki Wellfield in year 2000 and revised in 2002. Based on the Model prediction the sustainable pumping rate from the wellfield was proposed with a continuous monitoring of the pumping rate and drawdown. The wellfield commenced pumping in 2002 within the proposed pumping rate. Monitoring of the discharge and water level evolution through time is being done by Addis Ababa Water and Sewerage Authority (AAWSA). This case study is prepared to present the result of the monitoring work and the model prediction and deals with the importance of groundwater modeling for planning, design, implementation and management of groundwater resources.

Introduction

Akaki wellfield is situated to the southeast of Akaki town about 22 km south of the centre of Addis Ababa. The name Akaki is taken from the sub-city situated close to the wellfield and from the name of the river that drains Addis Ababa City. The wellfield covers an area of about 16-km2 and comprises 25 production wells and four monitoring wells.

The aquifers in the wellfield area are mainly from young volcanic rocks largely made of scoria, and fractured vesicular basalts with little to no weathering. The aquifer is largely due to processes related to lava flow and tectonic fractures. The aquifer to the north of the well field mainly covering the city of Addis Ababa and in the mountains north of the city are largely due to weathered and fractured volcanic rock with minor sediments deposited between different series of lava flows.

The main groundwater movement is from north to south in the central and northern part of the Akaki River catchment and towards the southeast direction in the lower part of the Catchment.

The potentiometer surface indicates that the groundwater is in connection with Akaki River about 5 km to the north of the wellfield. The base flow of Akaki River and its tributaries is mainly contributed from the groundwater. The recharge to the groundwater that takes place within Akaki River Catchment is considered contributing to the base flow.

Out of the 25 wells, 11 boreholes were planned for first phase development (for a production of about 72,000m^3) and the remaining 14 were planned for the second phase development for about 50,000 m^3/day, in total 125,000 m^3/day. However, before implementing the project AAWSA decided to conduct groundwater modelling for assessing the potential of the aquifer and predict the sustainable pumping rate from the aquifer. Therefore, Akaki groundwater was modelled using *Processing Modflow (PMWIN)* software developed by W.-H. Chiang & W. Kinzelbach. The first modelling was done in year 2000. Phase I boreholes commenced pumping following the recommendation from the modelling result. The year 2000 model result was revised in year 2002 by

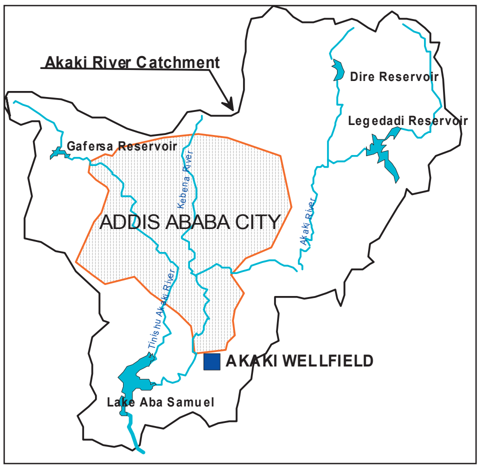

Figure 1. Location of Akaki Wellfield

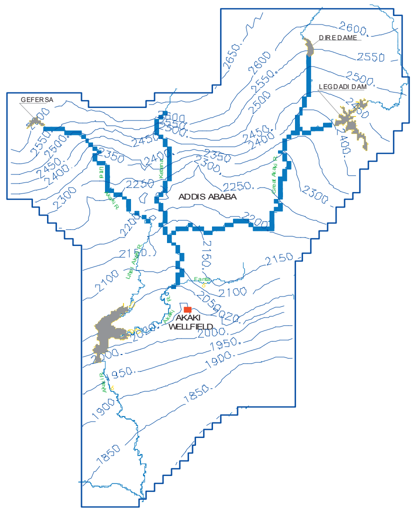

Figure 2. Model area and groundwater potentiometer levels

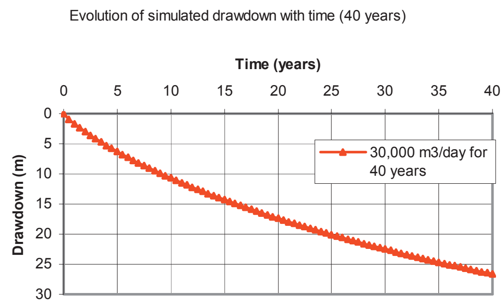

Figure 4. Drawdown in Akaki Wellfield resulting From Different Pumping Rates at 30,000m³/day (Akaki Groundwater Mode Report, Sept. 2000)

taking into account additional investigation results and the results from pumping of Phase I boreholes.

Akaki groundwater model 2000

The year 2000 Akaki groundwater model conducted different simulations as shown in figure 3 and 4 with different discharge rates and recommended reasonable exploitation of about 32000 m³/day for over 20 years of pumping. In addition to this it was recommended to investigate the deeper aquifer within the wellfield and other additional possible wellfield sites.

In Year 2002 Akaki Groundwater Model 2000 has been updated by taking into account the recommendations of the year 2000 model. Therefore according to the recommendation it has taken into account the monitoring results from Phase I boreholes and the results of additional drilled test wells. Based on this the model grid was expanded to cover additional possible well fields and the model parameters were recalibrated. The recalibrated result has shown reasonable mach between the observed and simulated drawdown due to pumping of Phase I boreholes between 30 November 2001 and 24 April 2002 as shown in figure 5 and table 1.

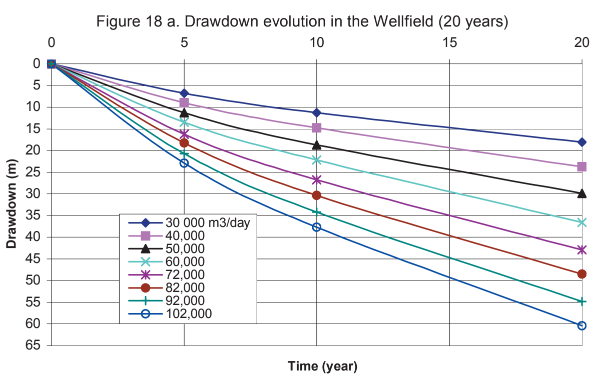

Figure 3. Drawdown in Akaki Wellfield resulting from different pumping rates (Akaki Groundwater Mode Report, Sept. 2000)

Monitoring results

Following the implementation of phase I pumps AAWSA continued monitoring the wellfield both the discharge rate

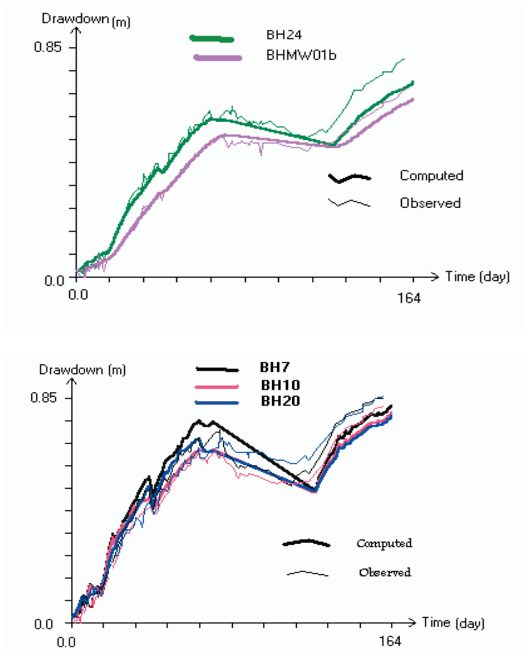

Figure 5. Observed and simulated Drawdown (Akaki Groundwater Mode Report, June 2002)

Table 1. Observed and computed drawdown after 164 days (Akaki Groundwater Mode Report, June 2002)

Borehole Number	Observed	Computed
BH07 (277)	0.83	0.82
BH10 (280)	0.83	0.79
BH20 (289)	0.86	0.79
BH24 (293)	0.81	0.72
BHMW01b (296)	0.76	0.66

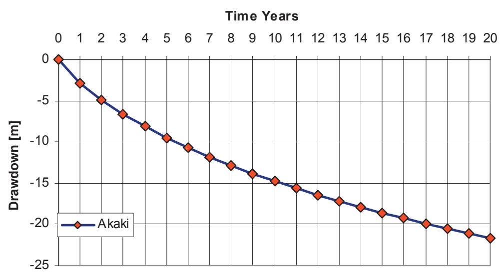

Figure 6. Drawdown caused by pumping 30,000m³/day (Akaki Groundwater Model Report, June 2002)

Table 2. Computed Drawdown at the centre of the wellfield (Akaki Groundwater Mode Report, June 2002)

Simulation Year	Simulated Drawdown
0	0.0
1	-2.9
2	-4.9
3	-6.6
4	-8.1
5	-9.5
10	-14.8
15	-18.6
20	-21.6

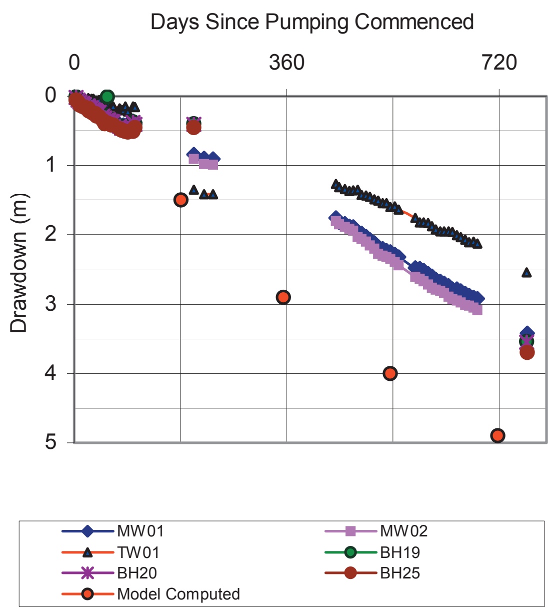

Figure 7. Drawdown resulting from pumping in the wellfield and model predicted drawdown

and drawdown. The wellfield commenced continuous pumping from March 2002 with initial average discharge of about 17, 000 m³/day and the pumping rate increased to average daily pumping rate of about 30,000 m³/day. The model computed drawdown for pumping rate of 30,000 m³/day and actually observed drawdown in the well field is shown in the figure 7 below. The result shows that the model has closely approximated the actual drawdown resulting from the pumping rate in the wellfield. As can be seen from the figure, there is a difference between the simulated and the actual drawdown. This difference is because the initial pumping rate was lower than 30,000m³/day.

Discussion of results

The modelling result has provided, clear picture about the magnitude of water that has to be produced from the well field.

It has saved unwanted investment in the groundwater development based on the initial estimate without the modelling (about 125,000 m³/day), which is four times more than the result obtained from the modelling.

It helped, in the planning for future water supply of the city by providing the potential of the groundwater that can be available for production from Akaki Wellfield.

Conclusions

The well field based on test pumping data and recharge estimation was initially expected to yield about 125,000 m³/day. However, the modelling result indicated its potential abstraction rate is in the order of 30, 000 m³/day. The two years pumping rate and drawdown monitoring has also indicated that the model has closely predicted the potential of the wellfield.

Akaki wellfield is a good example for the application of groundwater models in groundwater resources development and management.

Groundwater modelling is a good tool to estimate the resource and predict impacts for development of large abstractions, such as cities, towns' water supply and groundwater based irrigation schemes. It also helps to avoid unnecessary investment on the resource.

Regional or basin wide groundwater modelling would help to plan and develop the groundwater resource without affecting the environment and the potential of the resource. Its prediction capacity especially makes it suitable to estimate the groundwater resources that would be available for the future. This predicted potential could be compared with the potential water demand in the future.

References

BCEOM and Seureca Space JV in association with Tropics Consulting Engineers, June 2002; Model Verification for Akaki Groundwater Resources and Proposed Development Alternatives. Addis Ababa Water Supply Project Stage IIIA, Groundwater Phase II. Addis Ababa Water & Sewerage Authority (AAWSA), Addis Ababa.

BCEOM and Seureca Space JV in association with Tropics Consulting Engineers, September 2000; Akaki Groundwater Model. Addis Ababa Water Supply Project Stage IIIA, Groundwater Phase II. Addis Ababa Water & Sewerage Authority (AAWSA), Addis Ababa.

Note/s

1. AAWSA (Addis Ababa Water and Sewerage Authority

Contact address

Shiferaw Lulu
Sinior Hydrogeologist and Deputy Manager of AG-Consult Consulting Hydrogeologists and Engineers
P. Box. 4661, E-mail ag-consult@telecom.net.et
Addis Ababa, Ethiopia

Abebe G/Hiwot
Sinior Hydrogeologist and Manager of AG-Consult Consulting Hydrogeologists and Engineers
P. Box. 4661, E-mail ag-consult@telecom.net.et
Addis Ababa, Ethiopia

Kebede Tsehayu
Senior Hydrogeologist
Addis Ababa Water and Sewerage Authority (AAWSA)
Addis Ababa, Ethiopia

Solomon Waltanigus
Sinior Hydrogeologist
Addis Ababa Water and Sewerage Authority (AAWSA)
Addis Ababa, Ethiopia