GROUNDWATER MANAGEMENT USING GROUNDWATER MODELING: Case Study on Akaki Groundwater Model

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Abstract

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

The wellfield is situated to the southeast of Akaki town about 22 km south of the centre of Addis Ababa. The wellfield covers an area of about 16-km^2. 25 production wells and four monitoring wells were drilled within this area.

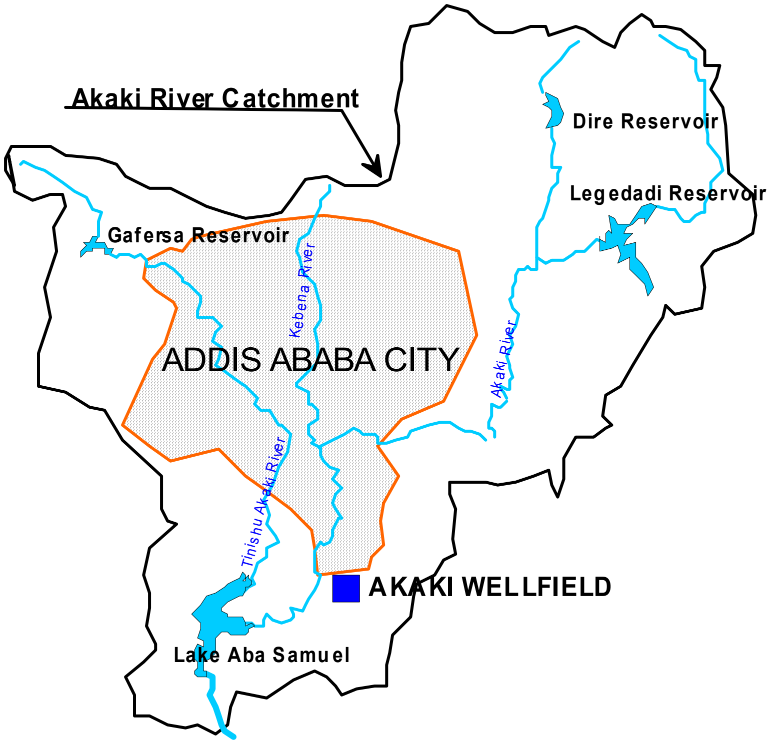

Figure 1. Location of Akaki Wellfield

All the 25 production wells are situated to the south of the main Addis Ababa -Djibouti highway.

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 Addis Ababa city and in the mountain area 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 in the southeast direction (towards Dukem plain) in the lower part of the Catchment.

The potentiometer surface indicates that the groundwater is in connection with the surface water mainly with Big and Small Akaki River to the north of the Akaki Bridge. The base flow in these rivers is mainly contributed from the groundwater. The recharge to the groundwater which takes place within the Akaki River Catchment to the north of Akaki Bridge is considered contributing to the base flow.

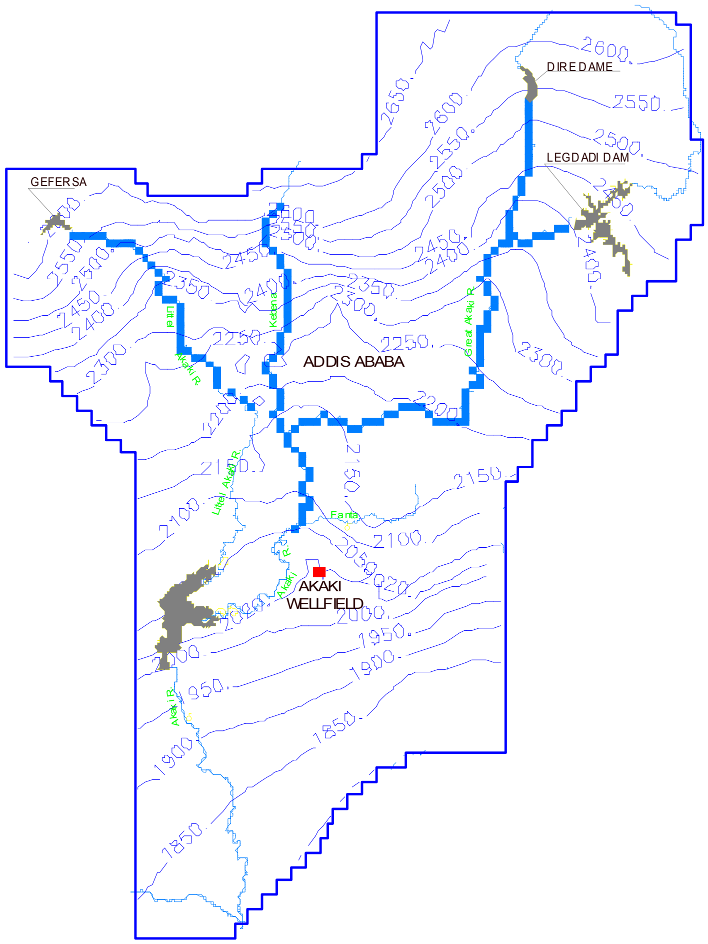

Figure 2. Model area and groundwater potentiometer levels

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

Akaki Ground Water 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 m^3/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.

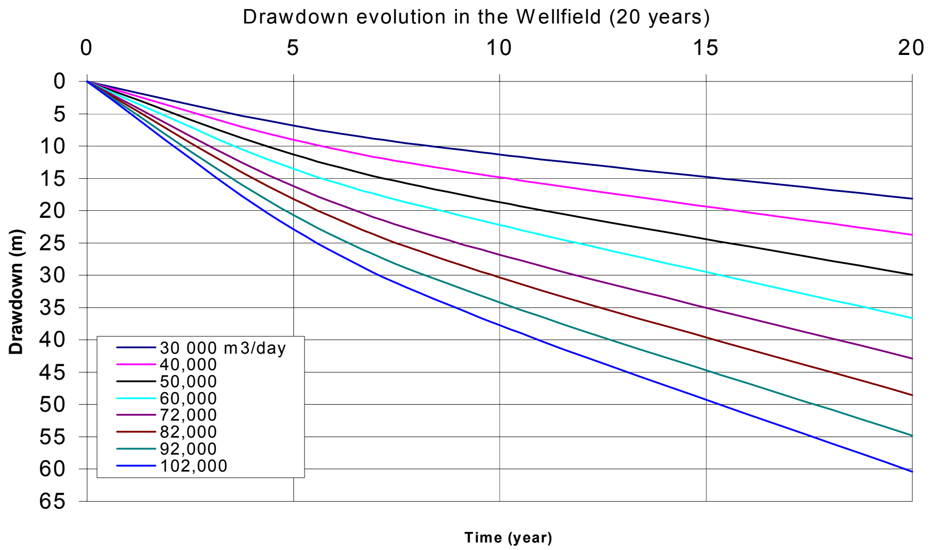

Figure 3. Drawdown in Akaki Wellfield resulting From Different Pumping Rates (Akaki Groundwater Mode Report, Sept.2000)

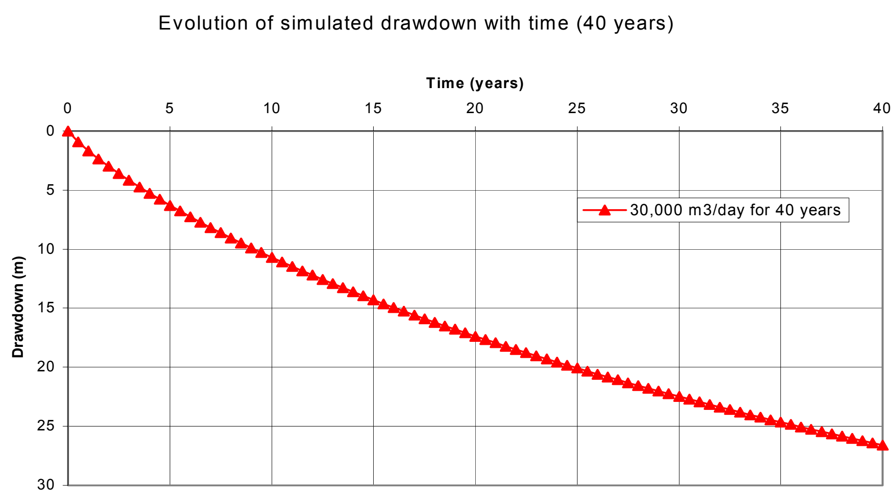

Figure 4. Drawdown in Akaki Wellfield resulting From Different Pumping Rates at 30,000m^3/day(Akaki Groundwater Mode Report, Sept.2000)

Akaki Groundwater Model 2002

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.

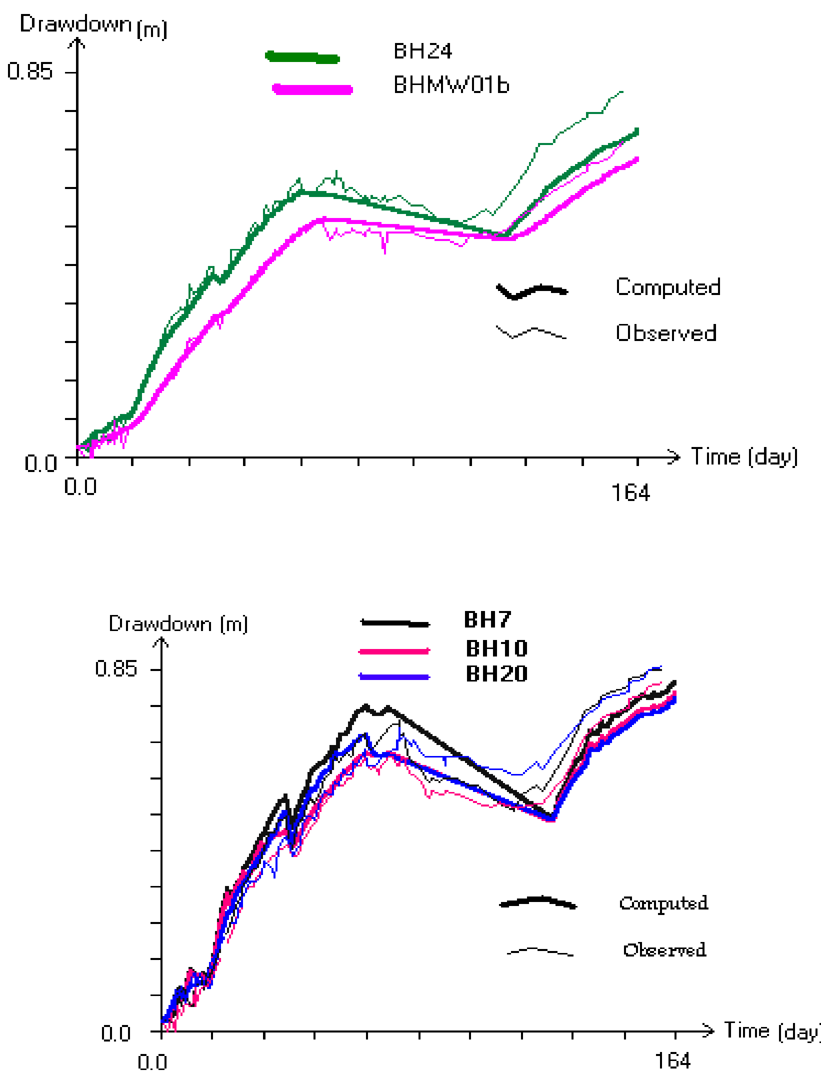

Figure 5. Observed and simulated Drawdown (Akaki Groundwater Mode Report, June 2002)

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

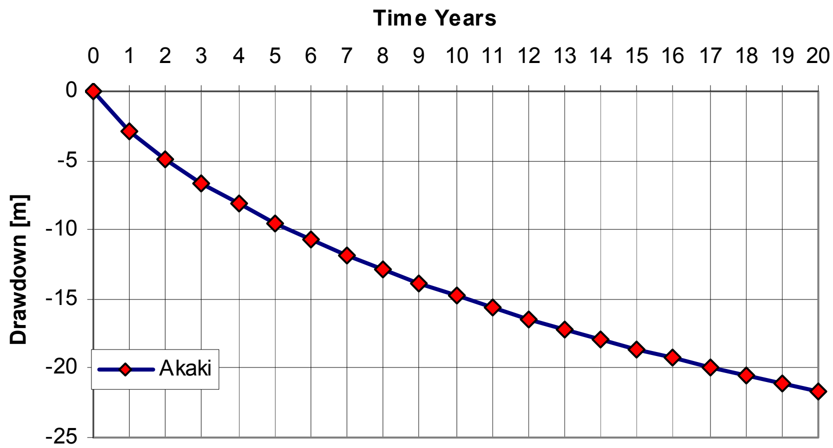

Figure 6. Drawdown Caused by pumping 30,000m^3/day (Akaki Groundwater Mode Report, June 2002)

Table 2. Computed Drawdown at the centre of the wellfild (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

Monitoring Results

Following the implementation of phase I pumps AAWSA continued monitoring the wellfield both discharge and drawdown. The wellfield commenced continuous pumping from March 2002 with initial average discharge of about 17, 000 m^3/day and the pumping rate increased to average daily pumping rate of about 30,000 m^3/day in the past one year. The model computed drawdown for pumping rate of 30,000 m^3/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 not 30,000m^3/day.

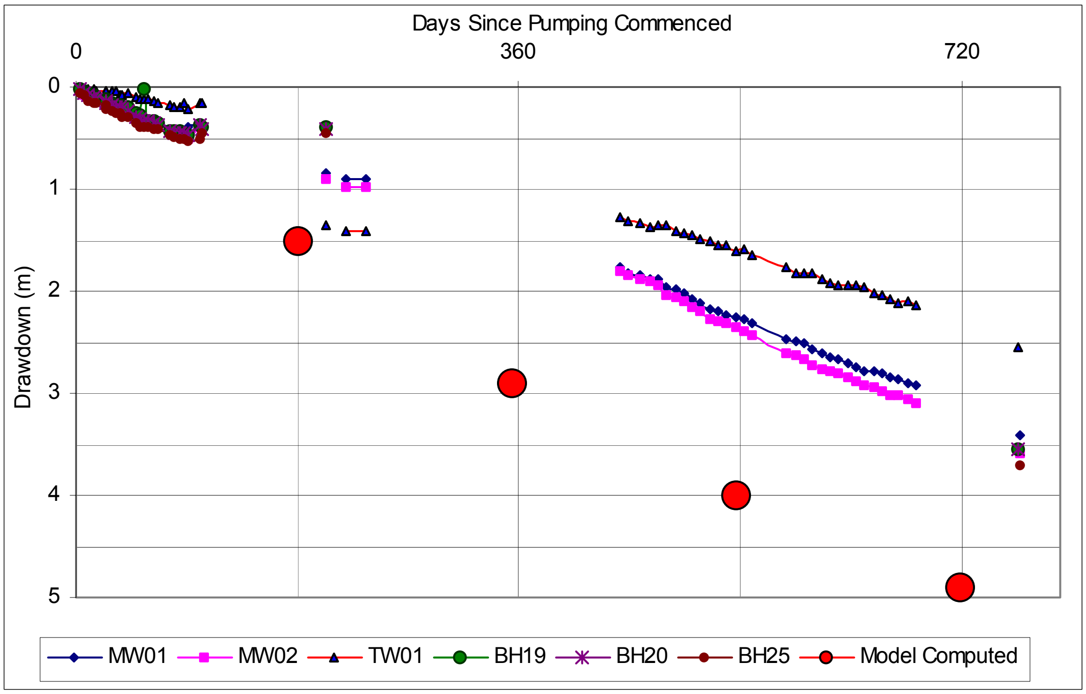

Figure. 7 Drawdown resulting from pumping in the wellfield and model predicted drawdown

Discussion of Results

The modelling result has provided AAWSA, 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 AAWSA, in its future plan for water supply of the city by providing the potential of the groundwater that can be available for production.

More than 25 towns and cities in Ethiopia are obtaining their potable water from groundwater source (boreholes). Few of the major groundwater based towns and cities are shown in table 3 below.

Table 3. Some of the towns and cities in Ethiopia supplied from Groundwater

Towns	Major Rocks
Addis Ababa (Partially)	Volcanic Rocks
Combolcha	Alluvial Deposits
Debre Zeit	Volcanic Rocks
Mojo	Volcanic Rocks
Mekele	Dolerites within Mesozoic Sedimentary Rocks
Dire Dawa	Mesozoic Sandstones
Debre Markos	Volcanic Rocks
Dessie	Alluvial Deposits
Gonder	Volcanic Rocks
Bichena	Volcanic Rocks
Asayta	Volcanic Rocks
Butajira	Alluvial Deposits & Volcanic Rocks
Welkite	Volcanic Rocks
Harar (Dire Jara)	Mesozoic Sedimentary rocks alluvial deposits and Volcanic Rocks
Logia & Semera	Alluvial Sediments

Except Addis Ababa the groundwater resource potentials for all groundwater based towns and cities were not evaluated with recent groundwater evaluation technique, i.e. groundwater modelling.

Most of the groundwater based water supply projects were launched before the groundwater modelling and environmental management concepts were not given due attention in the country. Therefore, there was a missed gap regarding the integrated resource management approach and thereby assuring environmentally and potentially sustainable projects.

The initiation taken by AAWSA is an exemplary for sustainable groundwater resources development and management.

Some problems resulting from miss management, resource limitations and over designs are being felt recently in some of the towns such as Mekele, Gonder, Axum, etc. Therefore, there is a desire to apply these techniques in the existing and new projects to assure sustainability of groundwater projects. An improper development would lead to the conclusion that groundwater is unreliable resource. However, it should be noted that groundwater is cheap, sustainable and environmentally less vulnerable as compared to surface water. It is a reliable resource, however, it requires careful development and management.

Apart from specifically targeted projects, groundwater models can be used to assess, regional or river basins groundwater potentials. Such types of works are very useful for planning, development and management of regional or basin wide groundwater resources.

Conclusions

The well field based on test pumping data and recharge estimation was initially expected to yield about 125,000 m^3/day. However, the modelling result indicated its potential abstraction rate is in the order of 30, 000 m^3/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 resources development for large abstractions, such as cities, towns' water supply and groundwater based irrigation schemes groundwater modelling is a good tool to estimate the resource and predict its impacts. 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 & 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.

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