Application of iMOD Groundwater Model to Coastal Area of Mekong Delta, Vietnam

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1. Introduction

Mekong Delta (MD) is one of the most vulnerable regions in the world under impacts of the climate change. Possible effects of climate change have been reported widely in some studies for MD and there is no reason to believe that climate change will not influence subsurface conditions such as groundwater (GW) levels. Under rapid increase in water demand due to the increasing population, GW is an important hidden resource for water use, particularly utilized in the study area, a coastal zone of MD (Fig.1). GW drawdown phenomenon caused by excessive GW use has been observed clearly in the study area (Fig.2) especially in exploited aquifers [1]. Our investigation results in the study area in 2013 showed saltwater intrusion into aquifers resulting significant deterioration of the GW quality [2], and it was considered to be caused by GW table drawdown. In this situation, assessment tools of GW resources are necessary for long term period. Development or application GW model is very essential in GW management, and appropriate models setting will help in analyzing impacts of GW extraction to understand GW situation in future [3]. In this study, iMOD GW model was calibrated using the historical data collected during 1994 – 2013, and then applied to predict the GW levels under combination of projected future rainfall and the volume of GW abstraction. Simulations for transient scenarios of A1, A2, A3 and steady state risk scenarios of B2, C2 (Tab.1) for piezometric heads at abstracted aquifer (Pleistocene) were carried out by using the study area's rainfall outputs (2015-2035) of the downscaled PRECIS model adjusted by a bias correction method and projected GW exploitation in future (Fig.3).

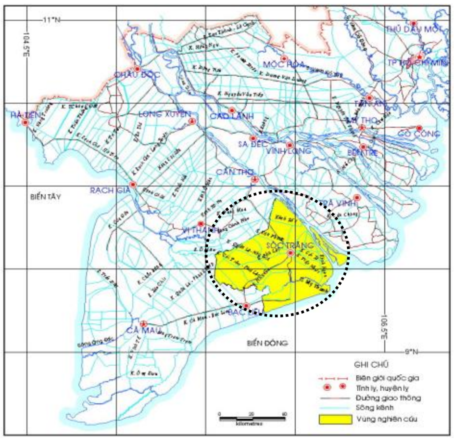

Fig. 1 The study area in MD (DONRes, 2012).

2. Methodology

2.1 Rainfall series generation

The projected precipitation for the future was downscaled from the global climate model by the Southeast Asia START Regional Center [4]. The downscaled model (PRECIS) has been used to downscale from the GCM of ECHAM4 with resolution of (20km x 20km) for whole the Mekong basin up to 2035. Rainfall time series from the SocTrang meteorological station close to GW monitoring station of Q589030 in center of study area was selected as a representative of the whole study area to be used for simulating the GW piezometric heads (Fig. 2) However, there were significant differences between the downscaled model (PERCIS) estimates and observed rainfall. Based on the bias correction method, the rainfall series for the future of 21-year period (2015-2035) was adjusted by calibration for the 20-year period (1980-1999) daily rainfall series.

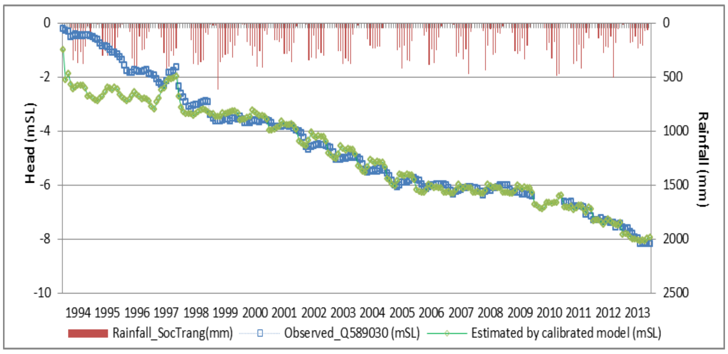

Fig 2. Observed & simulated results of GW heads at Q589030 by considering rainfall.

Tab.1 Summary of rainfall change and GW abstraction scenarios.

Scenarios	Driver	Assumption
GW abstraction		
1	Baseline situation	Current extraction rate is maintained
2	Increased supply	Abstraction increase of 1.8% per year
3	Conservative policies	Abstraction is reduced to 1% per year
Rainfall change		
A	Baseline situation	Projected rainfall adjusted from PERCIS
B	Minor (SRES B1)	Reduction of rainfall by 5% in 2035
C	Major (SRES A2)	Reduction of rainfall by 15% in 2035

2.2. Groundwater abstraction (scenario 1-3)

The first scenario (1) is that current GW extraction should be maintained. However, water consumption will continue to increase alongside increasing population and industrial production. Thus, in scenario 2, GW abstraction rates for domestic, industrial and agricultural supply were set up based on projections made by experts and stakeholders for future trends in water demand and consumption. For the period of 5 years (2015 – 2020), the total GW demand is predicted to increase from 348.226 m^3/day to 379.916 m^3/day in study area [5], which means 1.8% per year in average (scenario 2). In case GW abstraction could not satisfy the potential future water demand, some technologies may apply to save water or optimize using of other water resources. Or, other measures may also be implemented for closure of wells in operation and their geographical reallocation, and management should focus on reducing the quota for GW abstraction. Under this assumption, GW extraction is predicted to reduce by 1% per year (scenario 3). This would help cut the decline of GW levels and protect limited water resources at the aquifer.

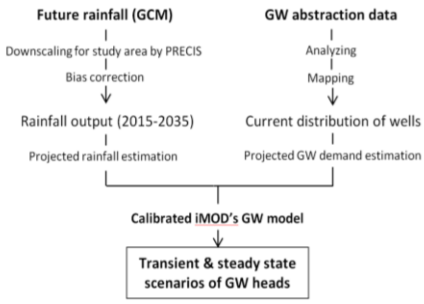

Fig 3. Schematic chart of model application.

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3 Results and discussion

3.1 Transient results for scenarios A1-3

The baseline scenario (A1) assumed that the current climatic and rainfall conditions and GW extraction should be maintained. The simulation results indicated that GW levels are mostly stabilized for the whole period with repeating slight drops and recoveries in each year (Fig. 4). According to this, the drop speed of GW levels can be reduced in comparison with the historical process in study area when the current extraction rate is maintained. For scenario A2, which is based on 1.8% increase per year in GW pumping, the results showed a significant declining trend GW level across the simulation period, which implies an imbalance between GW recharge and discharge. That is, aquifer depletion is taking place when GW is withdrawn faster than it is recharged by precipitation. The graph shows that if GW abstraction increases, there will be an overall decline in GW levels with around 2 m in the center and 3.5 m in the coastal districts of the study area, where extraction wells are densely located. In scenario A3, the benefit of GW resources protection with sustainable policy was tested. This sustainable scenario considers 1% reduction per year in pumping for water supply. This percentage value was selected to examine a sustainable GW pumping pattern. It is considered as an option which could significantly reduce GW level declines within the whole aquifer. In this case, since estimated recharge from projected rainfall is higher than discharge, GW levels can recover up to about 1 – 1.5 m in 2035. Hence, it is apparent that the proposed reduction of GW supply is the solution to cut the water level decline and to protect the scarce water resources at the aquifer. However, it would probably take several decades to restore the aquifer.

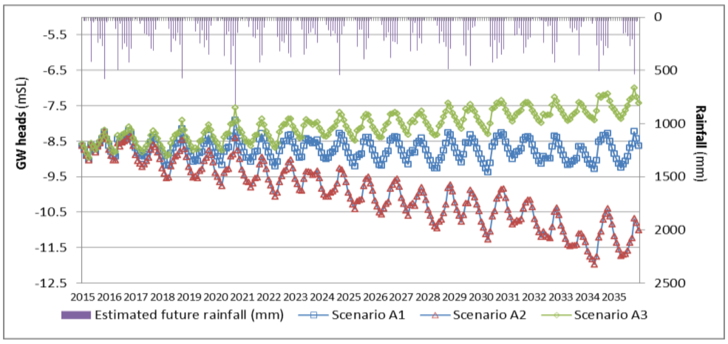

Fig 4. Simulated GW levels at Q589030 station for transient scenarios.

3.2 Steady-state results for risk scenarios B2 and C2

The risk scenarios of B2 and C2 were simulated for 2035 by combining of rainfall reduction and increase in GW abstraction. Results of these scenarios (Fig.5) showed an intense and continuing decline of the simulated GW heads, whose pattern represents the clear effect of a decreased recharge and an increased pumping. If these conditions occur in the future, significant depletion of the GW aquifer could appear in most of the area by 2035. This appears more evidently with highest decline ranging from -8.0 to -14 .0 m in the central and coastal areas where intensive pumping is occurring. Under C2 conditions, people in these areas would be most immediately vulnerable to water scarcity. Because the study area is coastal lowland of MD, the simulation results for both B2 and C2 scenarios imply that a further depletion of the GW table can cause land subsidence and salt intrusion in near future. Therefore, from model application to these scenarios, it can be concluded clearly that increasing pumping rates under the climate change conditions are not sustainable.

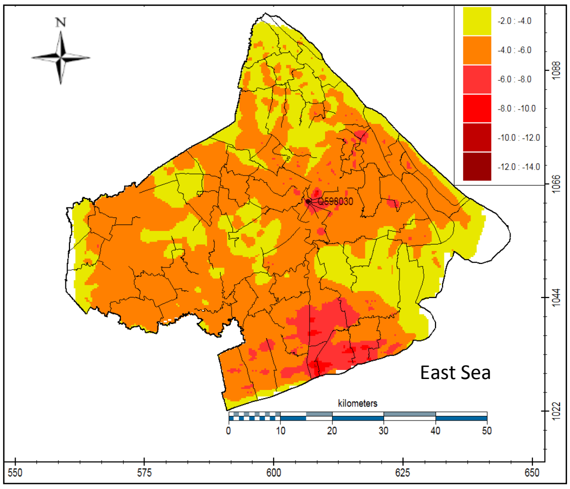

Fig 5. Simulated GW contours (mSL) of scenario C2 for Dec, 2035.

3.3 Discussion on accuracy of simulation results

Model outputs are expressed in terms of GW levels. Although a GW flow model can be a useful tool for investigating aquifer response, it is a simplified approximation of the actual system and is based on average or estimated conditions. The accuracy of its predictions depends on the availability and accuracy of the input data to be used to calibrate the model. In addition, in areas having sparse or no data, the accuracy of the model is reduced. Another possible source of inaccuracies is related to such input data as estimates of pumping and wells distribution. Although investigation of wells was carried out, it was difficult to get full wells data in the model because many of them could not be metered. Therefore, the assumed rate of GW pumping of agricultural and domestic wells may be overestimated or underestimated compared to the real pumping.

4. Conclusions

We ran the iMOD GW model for simulating various scenarios for 2015-2035 in order to examine the effects of the estimated change in rainfall and GW abstraction on the GW resource. As the results, the model predicted what is likely to happen on the GW aquifer for each scenario. These results allow the stakeholders to evaluate how well their interests would fare in terms of the available GW resources. People are able to see which areas may be more vulnerable to GW exhaustion and when this may happen. The Water Authority and the conservation groups are more interested in how modeling outputs represent a potential aquifer recovery. For the present rainfall condition, scenario A3, where the current rate of pumping in the whole study area is reduced by 1%, would be the best solution for sustainable GW use, because it can significantly reduce GW level declines and some recovery of GW levels can be expected. However, if we consider the strong trend of water demand increase and the future climate change, more intense regulations and control measures on GW use will be necessary.

References

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